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A. Cochran.
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THE

COLLECTED WORKS

OF

SIR HUMPHRY DAVY, Bart.

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SIR HUMPHRY DAVY, BART.

LL.D. F.R.S.

FOREIGN ASSOCIATE OF THE INSTITUTE OF FRANCE, ETC.

EDITED BY HIS BROTHER,

JOHN DAVY, M.D. F.R.S.

VOL. VIII.

AGRICULTURAL LECTURES, PART II.

AND

OTHER LECTURES.

LONDON:
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ELEMENTS

OF

AGRICULTURAL CHEMISTRY,

PART II.

MISCELLANEOUS LECTURES

AND

EXTRACTS FROM LECTURES.

LONDON:
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ELEMENTS

OF

AGRICULTURAL CHEMISTRY,

IN

A COURSE OF LECTURES

FOR

THE BOARD OF AGRICULTURE;

DELIVERED BETWEEN 1802 AND 1812.

ELEMENTS OF AGRICULTURAL CHEMISTRY.

LECTURE VI.

Of Manures of Vegetable and Animal Origin.—Of the Manner in which they become the Nourishment of the Plant.—Of Fermentation and Putrefaction.—Of the Different Species of Manures of Vegetable Origin; of the Different Species of Animal Origin.—Of mixed Manures.—General Principles with respect to the Use and Application of such Manures.

That certain vegetable and animal substances introduced into the soil accelerate vegetation and increase the product of crops, is a fact known since the earliest period of agriculture; but the manner in which manures act, the best modes of applying them, their relative value and durability, are still subjects of discussion. In this Lecture, I shall endeavour to lay down some settled principles on these objects; they are capable of being materially elucidated by the recent discoveries in chemistry; and I need not dwell on their great importance to farmers.

The pores in the fibres of the roots of plants are so small, that it is with difficulty they can be discovered by the microscope; it is not, therefore, probable that solid substances can pass into them from the soil. I tried an experiment on this subject: some impalpable powdered charcoal, procured by washing gunpowder, and dissipating the sulphur by heat, was placed in a phial containing pure water, in which a plant of peppermint was

growing: the roots of the plant were pretty generally in contact with the charcoal. The experiment was made in the beginning of May, 1805; the growth of the plant was very vigorous during a fortnight, when it was taken out of the phial: the roots were cut through in different parts; but no carbonaceous matter could be discovered in them, nor were the smallest fibrils blackened by charcoal, though this must have been the case, had the charcoal been absorbed in a solid form.

No substance is more necessary to plants than carbonaceous matter; and if this cannot be introduced into the organs of plants except in a state of solution, there is every reason to suppose that other substances less essential will be in the same case.

I found, by some experiments made in 1804, that plants introduced into strong fresh solutions of sugar, mucilage, tanning principle, jelly, and other substances, died; but that plants lived in the same solutions after they had fermented. At that time, I supposed that fermentation was necessary to prepare the food of plants; but I have since found, that the deleterious effect of the recent vegetable solutions was owing to their being too concentrated; in consequence of which the vegetable organs were probably clogged with solid matter, and the transpiration by the leaves prevented. In the beginning of June, in the next year, I used solutions of the same substances; but so much diluted, that there was only about $\frac{1}{200}$ part of solid vegetable or animal matter in the solutions. Plants of mint grew luxuriantly in all these solutions; but least so in that of astringent matter. I watered some spots of grass in a garden with the different solutions separately, and a spot with common water; the grass watered with solutions of jelly, sugar, and mucilage, grew most vigorously; and that watered

with the solution of the tanning principle grew better than that watered with common water.

I endeavoured to ascertain whether soluble vegetable substances passed in an unchanged state into the roots of plants, by comparing the products of the analysis of the roots of some plants of mint which had grown, some in common water, some in a solution of sugar: 120 grains of the roots of the mint, which grew in the solution of sugar, afforded five grains of pale green extract, which had a sweetish taste, but which slightly coagulated by the action of alcohol: 120 grains of the roots of the mint, which had grown in common water, yielded three grains and a half of extract, which was of a deep olive colour: its taste was sweetish, but more astringent than that of the other extract, and it coagulated more copiously with alcohol.

These results, though not quite decisive, favour the opinion that soluble matters pass unaltered into the roots of plants; and the idea is confirmed by the circumstance, that the radical fibres of plants, made to grow in infusions of madder, are tinged red; and it may be considered as almost proved by the fact, that substances, which are even poisonous to vegetables, are absorbed by them. I introduced the roots of a primrose into a weak solution of oxide of iron in vinegar, and suffered it to remain in it till the leaves became yellow; the roots were then carefully washed in distilled water, bruised, and boiled in a small quantity of the same fluid: the decoction of them passed through a filter, was examined by the test of infusion of nutgalls; the decoction gained a strong tint of purple, which proves that solution of iron had been taken up by the vessels or pores in the roots.

Vegetable and animal substances deposited in the

soil, as is shown by universal experience, are consumed during the process of vegetation; and they can only nourish the plant, by affording solid matters capable of being dissolved by water, or gaseous substances capable of being absorbed by the fluids in the leaves of vegetables; but such parts of them as are rendered gaseous, and that pass into the atmosphere, must produce a comparatively small effect; for gases soon become diffused through the mass of the surrounding air. The great object, in the application of manure, should be to make it afford as much soluble matter as possible to the roots of the plant; and that in a slow and gradual manner, so that it may be entirely consumed in forming its sap and organized parts.

Mucilaginous, gelatinous, saccharine, oily, extractive fluids, and solution of carbonic acid and water, are substances, that in their unchanged states contain almost all the principles necessary for the life of plants; but there are few cases in which they can be applied as manures, in their pure forms; and vegetable manures, in general, contain a great excess of fibrous and insoluble matter, which must undergo chemical changes before they can become the food of plants.

It will be proper to take a scientific view of the nature of these changes; of the causes which occasion them, and which accelerate or retard them; and of the products they afford.

If any fresh vegetable matter which contains sugar, mucilage, starch or other of the vegetable compounds, soluble in water, be moistened and exposed to air, at a temperature from 55° to 80°, oxygen will soon be absorbed, and carbonic acid formed; heat will be produced, and elastic fluids, principally carbonic acid, gaseous oxide of carbon, and hydro-carbonate will be

evolved; a dark-coloured liquid, of a slightly sour or bitter taste, will likewise be formed; and if the process be suffered to continue for a time sufficiently long, nothing solid will remain, except earthy and saline matter, coloured black by charcoal.

The dark-coloured fluid formed in the fermentation, always contains acetic acid; and when albumen or gluten exists in the vegetable substance, it likewise contains volatile alkali.

In proportion as there is more gluten, albumen, or matters soluble in water, in the vegetable substances exposed to fermentation, so in proportion, all other circumstances being equal, will the process be more rapid. Pure woody fibre alone undergoes a change very slowly; but its texture is broken down, and it is easily resolved into new elements, when mixed with substances more liable to change, containing more oxygen and hydrogen. Volatile and fixed oils, resins and wax, are more susceptible of change than woody fibre, when exposed to air and water, but much less liable than the other vegetable compounds; and even the most inflammable substances, by the absorption of oxygen, become gradually soluble in water.

Animal matters in general are more liable to decompose, than vegetable substances; oxygen is absorbed, and carbonic acid and ammonia formed in the process of their putrefaction. They produce fœtid compound elastic fluids, and likewise azote: they afford dark-coloured acid, and oily fluids, and leave a residuum of salts and earths mixed with carbonaceous matter.

The principal substances which constitute the different parts of animals, or which are found in their blood, their secretions, or their excrements, are gelatine, fibrine,

mucus, fatty or oily matter, albumen, urea, uric acid, and different acid, saline, and earthy matters.

Of these, *gelatine* is the substance which, when combined with water, forms jelly. It is very liable to putrefaction. According to MM. Gay Lussac and Thenard, it is composed of

47·88	of	carbon.
27·207	—	oxygen.
7·914	—	hydrogen.
16·998	—	azote.

These proportions cannot be considered as definite, for they do not bear to each other the ratios of any simple multiples of the number representing the elements; the case seems to be the same with other animal compounds: and even in vegetable substances in general, as appears from the statements given in the Third Lecture, the proportions are far from having the same simple relations as in the binary compounds capable of being made artificially; such as acids, alkalies, oxides, and in salts.

Fibrine constitutes the basis of the muscular fibre of animals; and a similar substance may be obtained from recent fluid blood: by stirring it with a stick, the fibrine will adhere to the stick. It is not soluble in water, but by the action of acids, as Mr. Hatchett has shown; it becomes soluble, and analogous to gelatine.* According to MM. Gay Lussac and Thenard, 100 parts of fibrine contain

Of carbon - -	53·360
— oxygen - -	19·685
— hydrogen - -	7·021
— azote - -	19·934

* [According to the results of my experiments, no animal substance putrefies more readily. Vide Anat. Physiol. Researches, vol. ii. p. 343.]

Mucus is very analogous to vegetable *gum*, in its characters; and, as Dr. Bostock has stated, it may be obtained by evaporating saliva. No experiments have been made upon its analysis; but it is probably similar to gum in composition. It is capable of undergoing putrefaction, but less rapidly than fibrine.

Animal fat and *oils* have not been accurately analysed; but there is great reason to suppose that their composition is analogous to that of similar substances from the vegetable kingdom.

Albumen has been already referred to, and its analysis stated in the Third Lecture.

Urea may be obtained by the evaporation of human urine, till it is of the consistence of a syrup, and the action of alcohol on the crystalline substance, which forms when the evaporated matter cools. In this way a solution of urea in alcohol is procured, and the alcohol may be separated from the urea, by heat. Urea is very soluble in water, and is precipitated from water by diluted nitric acid in the form of bright pearl-coloured crystals: this property distinguishes it from all other animal substances.

According to Fourcroy and Vauquelin, 100 parts of urea, when distilled, yield

92·027 parts of carbonate of ammonia.
4·608 carburetted hydrogen gas.
3·225 of charcoal.

Urea, particularly when mixed with albumen or gelatine, readily undergoes putrefaction.

Uric acid, as has been shown by Dr. Egan, may be obtained from human urine, by pouring an acid into it; and it often falls down from urine in the form of brick-coloured crystals. It consists of carbon, hydrogen, oxygen, and azote; but their proportions have not yet

been determined. Uric acid is one of the animal substances least liable to undergo the process of putrefaction.

According to the different proportions of these principles in animal compounds, so are the changes they undergo different. When there is much saline or earthy matter mixed or combined with them, the progress of their decomposition is less rapid, than when they are principally composed of fibrine, albumen, gelatine, or urea.

The ammonia given off from animal compounds in putrefaction, may be conceived to be formed at the time of their decomposition, by the combination of hydrogen and azote; except this matter, the other products of putrefaction are analogous to those afforded by the fermentation of vegetable substances; and the soluble substances formed abound in the elements, which are the constituent parts of vegetables, in carbon, hydrogen, and oxygen.

Whenever manures consist principally of matter soluble in water, it is evident that their fermentation or putrefaction should be prevented as much as possible; and the only cases in which these processes can be useful, are when the manure consists principally of vegetable or animal fibre. The circumstances necessary for the putrefaction of animal substances, are similar to those required for the fermentation of vegetable substances: a temperature above the freezing point; the presence of water, and the presence of oxygen, at least in the first stage of the process.

To prevent manures from decomposing, they should be preserved dry, defended from the contact of air, and kept as cool as possible.

Salt and alcohol appear to owe their powers of pre-

serving animal and vegetable substances to their attraction for water, by which they prevent its decomposing action, and likewise to their excluding air. The use of ice in preserving animal substances, is owing to its keeping their temperature low. The efficacy of M. Appert's method of preserving animal and vegetable substances, an account of which has been lately published, entirely depends upon the exclusion of air. This method is by filling a vessel of tin-plate or glass with the meat or vegetables; soldering or cementing the top so as to render the vessel air-tight; and then keeping it half immersed in a vessel of boiling water for a sufficient time to render the meat or vegetables proper for food. In this last process, it is probable that the small quantity of oxygen remaining in the vessel, is absorbed; for, on opening a tinned iron canister, which had been filled with raw beef, and exposed to hot water the day before, I found that the minute quantity of elastic fluid which could be procured from it, was a mixture of carbonic acid gas and azote.

Where meat or vegetable food is to be preserved on a large scale, for the use of the navy or army, for instance, I am inclined to believe, that by forcibly throwing a quantity of carbonic acid, hydrogen, or azote, into the vessel, by means of a compressing pump, similar to that used for making artificial Seltzer water, any change in the substance would be more effectually prevented. No elastic fluid in this case would have room to form by the decomposition of the meat; and the tightness and strength of the vessel would be proved by the process. No putrefaction or fermentation can go on without the generation of elastic fluid; and pressure would probably act with as much efficacy as cold in the preservation of animal or vegetable food.

As different manures contain different proportions of the elements necessary to vegetation, so they require a different treatment to enable them to produce their full effects in agriculture. I shall therefore describe in detail the properties and nature of the manures in common use, and give some general views respecting the best modes of preserving and applying them.

All *green succulent plants* contain saccharine or mucilaginous matter, with woody fibre, and readily ferment.

They cannot, therefore, if intended for manure, be used too soon after their death.

When *green crops* are to be employed for enriching a soil, they should be ploughed in, if it be possible, when in flower, or at the time the flower is beginning to appear; for it is at this period that they contain the largest quantity of easily soluble matter, and that their leaves are most active in forming nutritive matter. Green crops, pond weeds, the paring of hedges or ditches, or any kind of fresh vegetable matter, requires no preparation to fit them for manure. The decomposition slowly proceeds beneath the soil; the soluble matters are gradually dissolved, and the slight fermentation that goes on, checked by the want of a free communication of air, tends to render the woody fibre soluble without occasioning the rapid dissipation of elastic matter.

When old pastures are broken up and made arable, not only has the soil been enriched by the death and slow decay of the plants which have left soluble matters in the soil; but the leaves and roots of the grasses living at the time and occupying so large a part of the surface, afford saccharine, mucilaginous, and extractive matters, which become immediately the food of the

crop, and the gradual decomposition affords a supply for successive years.

Rape cake, which is used with great success as a manure, contains a large quantity of mucilage, some albuminous matter, and a small quantity of oil. This manure should be used recent, and kept as dry as possible before it is applied. It forms an excellent dressing for turnip crops ; and is most economically applied by being thrown into the soil at the same time with the seed. Whoever wishes to see this practice in its highest degree of perfection, should attend Mr. Coke's* annual sheep-shearing at Holkham.

Malt dust consists chiefly of the infant radicle separated from the grain. I have never made any experiment upon this manure; but there is great reason to suppose it must contain saccharine matter; and this will account for its powerful effects. Like rape cake, it should be used as dry as possible, and its fermentation prevented.

Linseed cake is too valuable as a food for cattle to be much employed as a manure; the analysis of linseed was referred to in the Third Lecture. The *water* in which *flax* and *hemp* are steeped for the purpose of obtaining the pure vegetable fibre, has considerable fertilizing powers. It appears to contain a substance analogous to albumen, and likewise much vegetable extractive matter. It putrefies very readily. A certain degree of fermentation is absolutely necessary to obtain the flax and hemp in a proper state: the water to which they have been exposed should therefore be used as a manure as soon as the vegetable fibre is removed from it.

Sea-weeds, consisting of different species of fuci,

[* Now Earl of Leicester.]

algæ, and confervæ, are much used as a manure on the sea-coasts of Britain and Ireland. By digesting the common fucus, which is the sea-weed usually most abundant on the coast, in boiling water, I obtained from it one-eighth of a gelatinous substance which had characters similar to mucilage. A quantity distilled gave nearly four-fifths of its weight of water, but no ammonia; the water had an empyreumatic and slightly sour taste: the ashes contained sea-salt, carbonate of soda, and carbonaceous matter. The gaseous matter afforded was small in quantity, principally carbonic acid and gaseous oxide of carbon, with a little hydro-carbonate. This manure is transient in its effects, and does not last for more than a single crop, which is easily accounted for from the large quantity of water, or the elements of water, it contains. It decays without producing heat when exposed to the atmosphere, and seems as it were to melt down and dissolve away. I have seen a large heap entirely destroyed in less than two years, nothing remaining but a little black fibrous matter. I suffered some of the firmest part of a fucus to remain in a close jar containing atmospheric air for a fortnight; in this time it had become very much shrivelled; the sides of the jar were lined with dew. The air examined was found to have lost oxygen, and contained carbonic acid gas.

Sea-weed is sometimes suffered to ferment before it is used; but this process seems wholly unnecessary, for there is no fibrous matter rendered soluble in the process, and a part of the manure is lost.

The best farmers in the west of England use it as fresh as it can be procured; and the practical results of this mode of applying it are exactly conformable to the theory of its operation. The carbonic acid formed

by its incipient fermentation must be partly dissolved by the water set free in the same process; and thus become capable of absorption by the roots of plants.

The effects of the sea-weed as manure must principally depend upon this carbonic acid, and upon the soluble mucilage the weed contains; and I found that some fucus which had fermented so as to have lost about half its weight afforded less than $\frac{1}{12}$ of mucilaginous matter; from which it may be fairly concluded that some of this substance is destroyed in fermentation.

Dry straw of wheat, oats, barley, beans and peas, and spoiled hay, or any other similar kind of dry vegetable matter, is, in all cases, useful manure. In general, such substances are made to ferment before they are employed, though it may be doubted whether the practice should be indiscriminately adopted.

From 400 grains of dry barley straw I obtained eight grains of matter soluble in water, which had a brown colour, and tasted like mucilage. From 400 grains of wheaten straw I obtained five grains of a similar substance.

There can be no doubt that the straw of different crops immediately ploughed into the ground affords nourishment to plants; but there is an objection to this method of using straw, from the difficulty of burying long straw, and from its rendering the husbandry foul.

When straw is made to ferment, it becomes a more manageable manure; but there is likewise on the whole a great loss of nutritive matter. More manure is perhaps supplied for a single crop; but the land is less improved than it would be, supposing the whole of the vegetable matter could be finely divided and mixed with the soil.

It is usual to carry straw that can be employed for no other purpose to the dunghill to ferment and decompose; but it is worth experiment, whether it may not be more economically applied when chopped small by a proper machine, and kept dry till it is ploughed in for the use of a crop. In this case, though it would decompose much more slowly, and produce less effect at first, yet its influence would be much more lasting.

Mere woody fibre seems to be the only vegetable matter that requires fermentation to render it nutritive to plants. Tanners' *spent bark* is a substance of this kind. Mr. Young, in his excellent Essay on Manures, which gained him the Bedfordian medal of the Bath Agricultural Society, states, "that spent bark seemed rather to injure than assist vegetation;" which he attributes to the astringent matter that it contains. But in fact it is freed from all soluble substances, by the operation of water in the tan-pit; and if injurious to vegetation, the effect is probably owing to its agency upon water, or to its mechanical effects. It is a substance very absorbent and retentive of moisture, and yet not penetrable by the roots of plants.

Inert peaty matter is a substance of the same kind. It remains for years exposed to water and air without undergoing change; and in this state yields little or no nourishment to plants.

Woody fibre will not ferment unless some substances are mixed with it which act the same part as the mucilage, sugar, and extractive or albuminous matters, with which it is usually associated in herbs, and succulent vegetables. Lord Meadowbank has judiciously recommended a mixture of common farm-yard dung for the purpose of bringing peats into fermentation; any putrescible or fermentable substance will answer the end;

and the more a substance heats, and the more readily it ferments, the better will it be fitted for the purpose.

Lord Meadowbank states, that one part of dung is sufficient to bring three or four parts of peat into a state in which it is fitted to be applied to land; but of course the quantity must vary according to the nature of the dung and of the peat. In cases in which some living vegetables are mixed with the peat, the fermentation will be more readily effected.

Tanners' spent bark, shavings of wood and sawdust, will probably require as much dung to bring them into fermentation as the worst kind of peat.

Woody fibre may be likewise prepared so as to become a manure by the action of lime. This subject I shall discuss in the next Lecture, as it follows naturally another series of facts relating to the effects of lime in the soil.

It is evident from the analysis of woody fibre by MM. Gay Lussac and Thenard (which shows that it consists principally of the elements of water and carbon, the carbon being in larger quantity than in the other vegetable compounds), that any process which tends to abstract carbonaceous matter from it must bring it nearer in composition to the soluble principles; and this is done in fermentation by the absorption of oxygen and production of carbonic acid; and a similar effect, it will be shown, is produced by lime.

Wood-ashes imperfectly formed, that is, wood-ashes containing much charcoal, are said to have been used with success as a manure. A part of their effects may be owing to the slow and gradual consumption of the charcoal, which seems capable, under other circumstances than those of actual combustion, of absorbing oxygen so as to become carbonic acid.

In April, 1803, I enclosed some well burnt charcoal in a tube half filled with pure water, and half with common air : the tube was hermetically sealed. I opened the tube under pure water in the spring of 1804, at a time when the atmospheric temperature and pressure were nearly the same as at the commencement of the experiment. Some water rushed in; and on expelling a little air by heat from the tube, and analyzing it, it was found to contain only seven per cent. of oxygen. The water in the tube, when mixed with lime-water, produced a copious precipitate ; so that carbonic acid had evidently been formed and dissolved by the water.

Manures from animal substances, in general, require no *chemical* preparation to fit them for the soil. The great object of the farmer is to blend them with the earthy constituents in a proper state of division, and to prevent their too rapid decomposition.

The entire parts of the muscles of land animals are not commonly used as a manure, though there are many cases in which such an application might be easily made. Horses, dogs, sheep, deer, and other quadrupeds that have died accidentally, or of disease, after their skins are separated are often suffered to remain exposed to the air, or immersed in water, till they are destroyed by birds or beasts of prey, or entirely decomposed; and in this case most of their organized matter is lost for the land in which they lie, and a considerable portion of it employed in giving off noxious gases to the atmosphere.

By covering dead animals with five or six times their bulk of soil, mixed with one part of lime, and suffering them to remain for a few months, their decomposition would impregnate the soil with soluble matters, so as to

render it an excellent manure, and by mixing a little fresh quicklime with it at the time of its removal the disagreeable effluvia would be in a great measure destroyed: and it might be applied in the same way as any other manure to crops.

Fish forms a powerful manure, in whatever state it is applied; but it cannot be ploughed in too fresh, though the quantity should be limited. Mr. Young records an experiment, in which herrings spread over a field and ploughed in for wheat produced so rank a crop that it was entirely laid before harvest.

The refuse pilchards in Cornwall are used throughout the county as a manure, with excellent effects. They are usually mixed with sand or soil, and sometimes with sea-weed, to prevent them from raising too luxuriant a crop. The effects are perceived for several years.

In the fens of Lincolnshire, Cambridgeshire, and Norfolk the little fish called sticklebacks are caught in the shallow waters in such quantities, that they form a great article of manure in the land bordering on the fens.

It is easy to explain the operation of fish as a manure. The skin is principally gelatine; which from its slight state of cohesion is readily soluble in water: fat or oil is always found in fishes, either under the skin or in some of the viscera; and their fibrous matter contains all the essential elements of vegetable substances.

Amongst oily substances, *blubber* has been employed as manure. It is most useful when mixed with clay, sand, or any common soil, so as to expose a large surface to the air, the oxygen of which produces soluble matter from it. Lord Somerville used blubber with great success at his farm in Surrey. It was made into

a heap with soil, and retained its powers of fertilizing for several successive years.

The carbon and hydrogen abounding in oily substances fully account for their effects; and their durability is easily explained from the gradual manner in which they change by the action of air and water.

Bones are much used as a manure in the neighbourhood of London. After being broken and boiled for grease, they are sold to the farmer. The more divided they are, the more powerful are their effects. The expense of grinding them in a mill would probably be repaid by the increase of their fertilizing powers; and in the state of powder they might be used in the drill husbandry, and delivered with the seed in the same manner as rape cake.

Bone dust and bone shavings, the refuse of the turning manufacture, may be advantageously employed in the same way.

The basis of bone is constituted by earthy salts, principally phosphate of lime, with some carbonate of lime and phosphate of magnesia; the easily decomposable substances in bone are fat, gelatine, and cartilage, which seem of the same nature as coagulated albumen.

According to the analysis of Fourcroy and Vauquelin, ox bones are composed,

Of decomposable animal matter - -	51
— phosphate of lime - - -	37·7
— carbonate of lime - - -	10
— phosphate of magnesia - -	1·3
	100

M. Merat Guillot has given the following estimate

of the composition of the bones of different animals:—*

	Phosphate of Lime.	Carbonate of Lime.
Bone of Calf - -	54	
——— Horse - -	67·5	1·25
——— Sheep - -	70	5
——— Elk - - -	90	1
——— Hog - -	52	1
——— Hare - -	85	1
——— Pullet - -	72	1·5
——— Pike - -	64	1
——— Carp - -	45	5
Horses' teeth - -	85·5	2·5
Ivory - - -	64	1

The remaining parts of the hundred must be considered as decomposable animal matter.

Horn is a still more powerful manure than bone, as it contains a larger quantity of decomposable animal matter. From 500 grains of ox horn Mr. Hatchett obtained only 1·5 grains of earthy residuum, and not quite half of this was phosphate of lime. The shavings or turnings of horn form an excellent manure, though they are not sufficiently abundant to be in common use. The animal matter in them seems to be of the nature of coagulated albumen, and it is slowly rendered soluble by the action of water. The earthy matter in horn, and still more that in bones, prevents the too rapid decomposition of the animal matter, and renders it very durable in its effects.

Hair, woollen rags, and *feathers,* are all analogous in composition, and principally consist of a substance similar to albumen, united to gelatine. This is shown by

* [In the first volume of the editor's Anatomical and Physiological Researches a more extensive table will be found of the composition of the bones of different animals.]

the ingenious researches of Mr. Hatchett. The theory of their operation is similar to that of bone and horn shavings.

The *refuse* of the different manufactures of *skin* and *leather* form very useful manures; such as the shavings of the currier, furriers' clippings, and the offals of the tan-yard and of the glue-maker. The gelatine contained in every kind of skin is in a state fitted for its gradual solution or decomposition; and when buried in the soil, it lasts for a considerable time, and constantly affords a supply of nutritive matter to the plants in its neighbourhood.

Blood contains certain quantities of all the principles found in other animal substances, and is consequently a very good manure. It has been already stated that it contains fibrine; it likewise contains albumen: the red particles in it, which have been supposed by many foreign chemists to be coloured by iron in a particular state of combination with oxygen and acid matter, Mr. Brande considers as formed of a peculiar animal substance, containing very little iron.

The scum taken from the boilers of the sugar bakers, and which is used as manure, principally consists of bullocks' blood, which has been employed for the purpose of separating the impurities of common brown sugar, by means of the coagulation of its albuminous matter by the heat of the boiler.

The different species of *corals, corallines,* and *sponges,* must be considered as substances of animal origin. From the analysis of Mr. Hatchett, it appears that all these substances contain considerable quantities of a matter analogous to coagulated albumen; the sponges afford likewise gelatine.

According to Merat Guillot, white coral contains

equal parts of animal matter and carbonate of lime; red coral 46·5 of animal matter and 53·5 of carbonate of lime; articulated coralline 51 of animal matter, and 49 of carbonate of lime.

These substances are, I believe, never used as manure in this country, except in cases when they are accidentally mixed with sea-weed; but it is probable that the corallines might be advantageously employed, as they are found in considerable quantity on the rocks and bottoms of the rocky pools in many parts of our coast, where the land gradually declines towards the sea; and they might be detached by hoes, and collected without much trouble.

Amongst excrementitious animal substances used as manures, *urine* is the one upon which the greatest number of chemical experiments have been made, and the nature of which is best understood.

The urine of the cow contains, according to the experiments of Mr. Brande,

Of water - - - -	65
— phosphate of lime - - -	3
— muriates of potassa and ammonia -	15
— sulphate of potassa - -	6
— carbonates of potassa, and ammonia	4
— urea - - - -	4

The urine of the horse, according to Fourcroy and Vauquelin, contains

Of carbonate of lime - - -	11
— carbonate of soda - - -	9
— benzoate of soda - - -	24
— muriate of potassa - - -	9
— urea - - - -	7
— water and mucilage - -	940

In addition to these substances, Mr. Brande found in it phosphate of lime.

The urine of the ass, the camel, the rabbit, and domestic fowls, has been submitted to different experiments, and the constitution has been found similar. In the urine of the rabbit, in addition to most of the ingredients above mentioned, Vauquelin detected gelatine; and the same chemist discovered uric acid in the urine of domestic fowls.

Human urine contains a greater variety of constituents than any other species examined.

Urea, uric acid, and another acid similar to it in nature, called rosacic acid, acetic acid, albumen, gelatine, a resinous matter, and various salts, are found in it.

The human urine differs in composition according to the state of the body, and the nature of the food and drink made use of. In many cases of disease there is a much larger quantity of gelatine and albumen than usual in the urine; and in diabetes it contains sugar.

It is probable that the urine of the same animal must likewise differ according to the different nature of the food and drink used; and this will account for discordances in some of the analyses that have been published on the subject.

Urine is very liable to change and to undergo the putrefactive process; and that of carnivorous animals more rapidly than that of graminivorous animals. In proportion as there is more gelatine and albumen in urine, so in proportion does it putrefy more quickly.

The species of urine that contain most albumen, gelatine, and urea, are the best as manures; and all urine contains the essential elements of vegetables in a state of solution.

During the putrefaction of urine the greatest part of

the soluble animal matter that it contains is destroyed; it should consequently be used as fresh as possible; but if not mixed with solid matter, it should be diluted with water, as when pure it contains too large a quantity of animal matter to form a proper fluid nourishment for absorption by the roots of plants.

Putrid urine abounds in ammoniacal salts; and though less active than fresh urine, is a very powerful manure.

According to a recent analysis published by Berzelius, 1000 parts of urine are composed of

Water - - - -	933
Urea - - - -	30·1
Uric acid - - - -	1
Muriate of ammonia, free lactic acid, lactate of ammonia, and animal matter - - -	17·14

The remainder, different salts, phosphates, sulphates, and muriates.

Amongst excrementitious solid substances used as manures, one of the most powerful is the *dung* of *birds*, that feed on *animal food*, particularly the dung of sea birds. The *guano*, which is used to a great extent in South America, and which is the manure that fertilizes the sterile plains of Peru, is a production of this kind. It exists abundantly, as we are informed by M. Humboldt, on the small islands in the South Sea, at Chinche, Ilo, Iza, and Arica. Fifty vessels are laden with it annually at Chinche, each of which carries from 1500 to 2000 cubical feet. It is used as a manure only in very small quantities, and particularly for crops of maize. I made some experiments on specimens of guano, sent from South America to the Board of Agriculture, in 1805. It appeared as a fine brown powder; it blackened

by heat, and gave off strong ammoniacal fumes; treated with nitric acid, it afforded uric acid. In 1806, MM. Fourcroy and Vauquelin published an elaborate analysis of guano. They state that it contains a fourth part of its weight of uric acid, partly saturated with ammonia, and partly with potassa; some phosphoric acid combined with the same bases, and likewise with lime, small quantities of sulphate and muriate of potassa, a little fatty matter, and some quartzose sand.

It is easy to explain its fertilizing properties: from its composition it might be supposed to be a very powerful manure. It requires water for the solution of its soluble matter, to enable it to produce its full beneficial effect on crops.

The dung of sea birds has, I believe, never been used as a manure in this country; but it is probable that even the soil of the small islands on our coast, much frequented by them, would fertilize. Some dung of sea birds, brought from a rock on the coast of Merionethshire, produced a powerful but transient effect on grass. It was tried, at my request, by Sir Robert Vaughan, at Nannau.

The rains, in our climate, must tend very much to injure this species of manure, where it is exposed to them, soon after its deposition; but it may probably be found in great perfection in caverns or clefts in rocks, haunted by cormorants and gulls. I examined some recent cormorant's dung, which I found on a rock near Cape Lizard, in Cornwall. It had not at all the appearance of the guano; was of a greyish white colour; had a very fœtid smell, like that of putrid animal matter: when acted on by quicklime, it gave abundance of ammonia; treated with nitric acid, it yielded uric acid.

Night-soil, it is well known, is a very powerful ma-

nure, and very liable to decompose. It differs in its composition; but always abounds in substances composed of carbon, hydrogen, azote, and oxygen. From the analysis of Berzelius, it appears that a part of it is always soluble in water; and in whatever state it is used, whether recent or fermented, it supplies abundance of food to plants.

The disagreeable smell of night-soil may be destroyed by mixing it with quicklime; and if exposed to the atmosphere in thin layers strewed over with quicklime in fine weather, it speedily dries, is easily pulverized, and in this state may be used in the same manner as rape-cake, and delivered into the furrow with the seed.

The Chinese, who have more practical knowledge of the use and application of manures than any other people existing, mix their night-soil with one-third of its weight of a fat marl, make it into cakes, and dry it by exposure to the sun. These cakes, we are informed by the French missionaries, have no disagreeable smell, and form a common article of commerce of the empire.

The earth, by its absorbent powers, probably prevents, to a certain extent, the action of moisture upon the dung, and likewise defends it from the effects of air.

After night-soil, *pigeons' dung* comes next in order, as to fertilizing power. I digested 100 grains of pigeons' dung in hot water for some hours, and obtained from it 23 grains of soluble matter; which afforded abundance of carbonate of ammonia by distillation; and left carbonaceous matter, saline matter principally common salt, and carbonate of lime, as a residuum. Pigeons' dung, when moist, readily ferments, and after fermentation contains less soluble matter than before: from 100 parts of fermented pigeons' dung, I obtained only eight parts of soluble matter, which gave proportionally less

carbonate of ammonia in distillation than recent pigeons dung.

It is evident that this manure should be applied a new as possible; and when dry, it may be employed in the same manner as the other manures capable of being pulverized.

The soil in woods where great flocks of wood-pigeons roost is often highly impregnated with their dung, and, it cannot be doubted, would form a valuable manure. I have found such soil yield ammonia when distilled with lime. In the winter, likewise, it usually contains abundance of vegetable matter, the remains of decayed leaves ; and the dung tends to bring the vegetable matter into a state of solution.

The dung of *domestic fowls* approaches very nearly in its nature to pigeons' dung. Uric acid has been found in it. It gives carbonate of ammonia by distillation, and immediately yields soluble matter to water. It is very liable to ferment.

The dung of fowls is employed in common with that of pigeons by tanners to bring on a slight degree of putrefaction in skins that are to be used for making soft leather; for this purpose the dung is diffused through water. In this state, it rapidly undergoes putrefaction, and brings on a similar change in the skin. The excrements of dogs are employed by the tanner with similar effects. In all cases, the contents of the *grainer*, as the pit is called in which soft skins are prepared by dung, must form a very useful manure.

Rabbits' dung has never been analysed. It is used with great success as a manure by Mr. Fane, who finds it profitable to keep rabbits in such a manner as to preserve their dung. It is laid on as fresh as possible, and is found better the less it has fermented.

The *dung* of *cattle*, *oxen*, and *cows*, has been chemically examined by MM. Einhof and Thaer. They found that it contained matter soluble in water; and that it gave in fermentation nearly the same products as vegetable substances, absorbing oxygen, and producing carbonic acid gas.

The recent *dung* of *sheep* and of *deer* afford, when long boiled in water, soluble matters, which equal from two to three per cent. of their weight. I have examined these soluble substances procured by solution and evaporation: they contain a very small quantity of matter analogous to animal mucus, and are principally composed of a bitter extract soluble both in water and in alcohol. They give ammoniacal fumes by distillation; and appear to differ very little in composition.

I watered some blades of grass for several successive days with a solution of these extracts: they evidently became greener in consequence, and grew more vigorously than grass in other respects under the same circumstances.

The part of the dung of cattle, sheep, and deer, not soluble in water, appears to be mere woody fibre, and precisely analogous to the residuum of those vegetables that form their food after they have been deprived of all their soluble materials.

The dung of horses gives a brown fluid, which, when evaporated, yields a bitter extract, which affords ammoniacal fumes more copiously than that from the dung of oxen.

If the pure dung of cattle is to be used as manure, like the other species of dung which have been mentioned, there seems no reason why it should be made to ferment, except in the soil; or if suffered to ferment, it should be only in a very slight degree. The grass in

the neighbourhood of recently voided dung is always coarse and dark green. Some persons have attributed this to a noxious quality in unfermented dung; but it seems to be rather the result of an excess of food furnished to the plants.

The question of the proper mode of the application of the dung of horses and cattle, however, properly belongs to the subject of *composite manures,* for it is usually mixed in the farm-yard with straw, offal, chaff, and various kind of litter; and itself contains a large proportion of fibrous vegetable matter.

A slight incipient fermentation is undoubtedly of use in the dunghill; for by means of it a disposition is brought on in the woody fibre to decay and dissolve, when it is carried to the land, or ploughed into the soil; and woody fibre is always in great excess in the refuse of the farm.

Too great a degree of fermentation is, however, very prejudicial to the composite manure in the dunghill; it is better that there should be no fermentation at all before the manure is used, than that it should be carried too far. This must be obvious from what has been already stated in this Lecture. The excess of fermentation tends to the destruction and dissipation of the most useful part of the manure; and the ultimate results of this process are like those of combustion.

It is a common practice amongst farmers to suffer the farm-yard dung to ferment till the fibrous texture of the vegetable matter is entirely broken down, and till the manure becomes perfectly cold, and so soft as to be easily cut by the spade.

Independent of the general theoretical views unfavourable to this practice founded upon the nature and composition of vegetable substances, there are many

arguments and facts which show that it is prejudicial to the interests of the farmer.

During the violent fermentation which is necessary for reducing farm-yard manure to the state in which it is called *short muck*, not only a large quantity of fluid, but likewise of gaseous matter, is lost; so much so, that the dung is reduced one-half, or two-thirds in weight; and the principal elastic matter disengaged is carbonic acid, with some ammonia; and both these, if retained by the moisture in the soil, as has been stated before, are capable of becoming an useful nourishment of plants.

In October, 1808, I filled a large retort, capable of containing three pints of water, with some hot fermenting manure, consisting principally of the litter and dung of cattle; I adapted a small receiver to the retort, and connected the whole with a mercurial pneumatic apparatus, so as to collect the condensible and elastic fluids which might rise from the dung. The receiver soon became lined with dew, and drops began in a few hours to trickle down the sides of it. Elastic fluid likewise was generated; in three days 35 cubical inches had been formed, which, when analysed, were found to contain 21 cubical inches of carbonic acid; the remainder was hydrocarbonate mixed with some azote, probably no more than existed in the common air in the receiver. The fluid matter collected in the receiver at the same time amounted to nearly half an ounce. It had a saline taste, and a disagreeable smell, and contained some acetate and carbonate of ammonia.

Finding such products given off from fermenting litter, I introduced the beak of another retort, filled with similar dung very hot at the time, into the soil amongst the roots of some grass in the border of a gar-

den; in less than a week a very distinct effect was produced on the grass; upon the spot exposed to the influence of the matter disengaged in fermentation, it grew with much more luxuriance than the grass in any other part of the garden.

Besides the dissipation of gaseous matter when fermentation is pushed to the extreme, there is another disadvantage in the loss of *heat*, which, if excited in the soil, is useful in promoting the germination of the seed, and in assisting the plant in the first stage of its growth, when it is most feeble and most liable to disease: and the fermentation of manure in the soil must be particularly favourable to the wheat crop in preserving a genial temperature beneath the surface late in autumn, and during winter.

Again, it is a general principle in chemistry, that in all cases of decomposition, substances combine much more readily at the moment of their disengagement, than after they have been perfectly formed. And in fermentation beneath the soil, the fluid matter produced is applied instantly, even whilst it is warm, to the organs of the plant, and consequently is more likely to be efficient than in manure that has gone through the process, and of which all the principles have entered into new combinations.

In the writings of scientific agriculturists, a great mass of facts may be found in favour of the application of farm-yard dung in a recent state. Mr. Young, in the Essay on Manures, which I have already quoted, adduces a number of excellent authorities in support of the plan. Many who doubted, have been lately convinced; and perhaps there is no subject of investigation in which there is such a union of theoretical and practical evidence. I have myself within the last ten years

witnessed a number of distinct proofs on the subject. I shall content myself with quoting that which ought to have, and which I am sure will have, the greatest weight among agriculturists. Within the last seven years, Mr. Coke, has entirely given up the system formerly adopted on his farm, of applying fermented dung; and he informs me that his crops have been since as good as they ever were, and that his manure goes nearly twice as far.

A great objection against slightly-fermented dung is, that weeds spring up more luxuriantly where it is applied. If there are seeds carried out in the dung, they certainly will germinate; but it is seldom that this can be the case to any extent; and if the land is not cleansed of weeds, any kind of manure, fermented or unfermented, will occasion their rapid growth. If slightly fermented farm-yard dung is used as a top-dressing for pastures, the long straws and unfermented vegetable matter remaining on the surface, should be removed as soon as the grass begins to rise vigorously, by raking, and carried back to the dunghill: in this case no manure will be lost, and the husbandry will be at once clean and economical.

In cases when farm-yard dung cannot be immediately applied to crops, the destructive fermentation of it should be prevented as much as possible: the principles on which this may be effected, have been already alluded to.

The surface should be defended as much as possible from the oxygen of the atmosphere; a compact marl, or a tenacious clay, offers the best protection against the air; and before the dung is covered over, or, as it were, sealed up, it should be dried as much as possible. If the dung is found at any time to heat strongly,

it should be turned over and cooled by exposure to air.

Watering dunghills, is sometimes recommended for checking the progress of fermentation; but this practice is inconsistent with just chemical views. It may cool the dung for a short time; but moisture, as I have before stated, is a principal agent in all processes of decomposition. Dry, fibrous matter, will never ferment. Water is as necessary as air to the process; and to supply it to fermenting dung, is to supply an agent which will hasten its decay.

In all cases when dung is fermenting, there are simple tests by which the rapidity of the process, and consequently the injury done, may be discovered.

If a thermometer plunged into the dung does not rise to above 100 degrees of Fahrenheit, there is little danger of much aëriform matter flying off. If the temperature is higher, the dung should be immediately spread abroad.

When a piece of paper, moistened in muriatic acid, held over the steams arising from a dunghill, gives dense u mes, it is a certain test that the decomposition is going too far; for this indicates that volatile alkali is disengaged.

When dung is to be preserved for any time, the situation in which it is kept, is of importance. It should, if possible, be defended from the sun. To preserve it under sheds would be of great use; or to make the site of a dunghill on the north side of a wall. The floor on which the dung is heaped should, if possible, be paved with flat stones; and there should be a little inclination from each side towards the centre, in which there should be drains connected with a small well, furnished with a pump, by which any fluid matter may be collected for

the use of the land. It too often happens that a dense mucilaginous and extractive fluid is suffered to drain away from the dunghill so as to be entirely lost to the farm.

Street and *road dung*, and the *sweepings of houses*, may be all regarded as composite manures; the constitution of them is necessarily various, as they are derived from a number of different substances. These manures are usually applied in a proper manner, without being fermented.

Soot, which is principally formed from the combustion of pit-coal, or coal, generally contains likewise substances derived from animal matters. This is a very powerful manure. It affords ammoniacal salts by distillation, and yields a brown extract to hot water, of a bitter taste. It likewise contains an empyreumatic oil. Its basis is charcoal, in a state in which it is capable of being rendered soluble by the action of oxygen and water.

This manure is well fitted to be used in the dry state, thrown into the ground with the seed, and requires no preparation.

The doctrine of the proper application of manures from organized substances, offers an illustration of an important part of the economy of nature, and of the happy order in which it is arranged.

The death and decay of animal substances, tend to resolve organized forms into chemical constituents: and the pernicious effluvia disengaged in the process, seem to point out the propriety of burying them in the soil, where they are fitted to become the food of vegetables. The fermentation and putrefaction of organized substances in the free atmosphere, are noxious processes; beneath the surface of the ground, they are salutary

operations. In this case, the food of plants is prepared where it can be used; and that which would offend the senses, and injure the health, if exposed, is converted by gradual processes into forms of beauty and of usefulness; the fetid gas is rendered a constituent of the aroma of the flower, and what might be poison, becomes nourishment to animals and to man.

LECTURE VII.

On Manures of Mineral Origin, or Fossil Manures; their Preparation, and the Manner in which they Act.—Of Lime in its Different States; Operation of Lime as a manure and a Cement; Different Combinations of Lime.—Of Gypsum; Ideas respecting its Use.—Of other Neutro-saline Compounds, employed as Manures.—Of Alkalies and Alkaline Salts; of Common Salt.

The whole tenor of the preceding Lectures shows that a great variety of substances contributes to the growth of plants, and supplies the materials of their nourishment. The conversion of matter that has belonged to living structures into organized forms, is a process that can be easily understood; but it is more difficult to follow those operations by which earthy and saline matters are consolidated in the fibre of plants, and by which they are made subservient to their functions. Some inquirers, adopting that sublime generalization of the ancient philosophers, that matter is the same in essence, and that the different substances considered as elements by chemists, are merely different arrangements of the same indestructible particles, have endeavoured to prove that all the varieties of the principles found in plants, may be formed from the substances in the atmosphere; and that vegetable life is a process in which bodies that the analytical philosopher is unable to change or to form are constantly composed and decomposed. These opinions have not been advanced merely as hypotheses: attempts have been made to support them by experiments. M. Schrader and M. Braconnot, from a series of distinct

investigations, have arrived at the same conclusions. They state that different seeds sown in fine sand, sulphur, and metallic oxides, and supplied only with atmospherical air and water, produced healthy plants, which by analysis yielded various earthy and saline matters, which either were not contained in the seeds, or the material in which they grew, or which were contained only in much smaller quantities in the seeds: and hence they conclude that they must have been formed from air or water, in consequence of the agencies of the living organs of the plant.

The researches of these two gentlemen were conducted with much ingenuity and address; but there were circumstances which interfered with their results, which they could not have known, as at the time their labours were published they had not been investigated.

I have found that common distilled water is far from being free from saline impregnations. In analyzing it by Voltaic electricity, I procured from it alkalies and earths; and many of the combinations of metals with chlorine are extremely volatile substances. When distilled water is supplied in an unlimited manner to plants, it may furnish to them a number of different substances, which, though in quantities scarcely perceptible in the water, may accumulate in the plant, which probably perspires only absolutely pure water.

In 1801 I made an experiment on the growth of oats, supplied with a limited quantity of distilled water in a soil composed of pure carbonate of lime. The soil and the water were placed in a vessel of iron, which was included in a large jar, connected with the free atmosphere by a tube, so curved as to prevent the possibility of any dust, or fluid, or solid matter from entering into the jar. My object was to ascertain whether any sili-

ceous earth would be formed in the process of vegetation; but the oats grew very feebly, and began to be yellow before any flowers formed: the entire plants were burnt, and their ashes compared with those from an equal number of grains of oat. Less siliceous earth was given by the plants than by the grains; but their ashes yielded much more carbonate of lime. That there was less siliceous earth, I attribute to the circumstance of the husk of the oat being thrown off in germination; and this is the part which most abounds in silica. Healthy green oats, taken from a growing crop, in a field of which the soil was a fine sand, yielded siliceous earth in a much greater proportion than an equal weight of the corn artificially raised.

The general results of this experiment are very much opposed to the idea of the composition of the earths, by plants, from any of the elements found in the atmosphere, or in water; and there are other facts contradictory to the idea. Jacquin states that the ashes of Glass-wort (*salsola soda*), when it grows in inland situations, affords the vegetable alkali; when it grows on the sea-shore, where compounds which afford the fossil or marine alkali are more abundant, it yields that substance. Du Hamel found that plants which usually grow on the sea-shore, made small progress when planted in soils containing little common salt. The sun-flower, when growing in lands containing no nitre, does not afford that substance; though when watered by a solution of nitre, it yields nitre abundantly. The tables of De Saussure, referred to in the Third Lecture, show that the ashes of plants are similar in constitution to the soils in which they have vegetated.

De Saussure made plants grow in solutions of differ-

ent salts, and he ascertained that in all cases certain portions of the salts were absorbed by the plant, and found unaltered in their organs.

Even animals do not appear to possess the power of forming the alkaline and earthy substances. Dr. Fordyce found, that when canary birds, at the time they were laying eggs, were deprived of access to carbonate of lime, their eggs had soft shells; and if there is any process for which nature may be conceived most likely to supply resources of this kind, it is that connected with the reproduction of the species.

As the evidence on the subject now stands, it seems fair to conclude, that the different earths and saline substances found in the organs of plants are supplied by the soils in which they grow; and in no cases composed by new arrangements of the elements in air or water. What may be our ultimate view of the laws of chemistry, or how far our ideas of elementary principles may be simplified, it is impossible to say. We can only reason from facts. We cannot imitate the powers of composition belonging to vegetable structures; but at least we can understand them: and, as far as our researches have gone, it appears that in vegetation compound forms are uniformly produced from simpler ones; and the elements in the soil, the atmosphere, and the earth, absorbed and made parts of beautiful and diversified structures.

The views which have been just developed lead to correct ideas of the operation of these manures, which are not necessarily the result of decayed organized bodies, and which are not composed of different proportions of carbon, hydrogen, oxygen, and azote. They must produce their effect, either by becoming a constituent part of the plant, or by acting upon its more

essential food, so as to render it more fitted for the purposes of vegetable life.

The only substances which can with propriety be called fossil manures, and which are found unmixed with the remains of any organized beings, are certain alkaline earths, or alkalies, and their combinations.

The only alkaline earths which have been hitherto applied in this way, are lime and magnesia. Potassa and soda, the two fixed alkalies, are both used in certain of their chemical compounds. I shall state in succession such facts as have come to my knowledge respecting each of these bodies in their applications to the purposes of agriculture; but I shall enlarge most upon the subject of lime; and if I should enter into some details which may be tedious and minute, I trust, my excuse will be found in the importance of the inquiry; and it is one which has been greatly elucidated by late discoveries.

The most common form in which lime is found on the surface of the earth, is in a state of combination with carbonic acid or fixed air. If a piece of limestone, or chalk, be thrown into a fluid acid, there will be an effervescence. This is owing to the escape of the carbonic acid gas. The lime becomes dissolved in the liquor.

When limestone is strongly heated, the carbonic acid gas is expelled, and then nothing remains but the pure alkaline earth: in this case there is a loss of weight; and if the fire has been very high, it approaches to one-half the weight of the stone; but in common cases, limestones, if well dried before burning, do not lose much more than from 30 to 40 per cent., or from seven to eight parts out of 20.

I mentioned, in discussing the agencies of the atmosphere upon vegetables, in the beginning of the Fifth

Lecture, that air always contains carbonic acid gas, and that lime is precipitated from water by this substance. When burnt lime is exposed to the atmosphere, in a certain time it becomes mild, and is the same substance as that precipitated from lime-water; it is combined with carbonic acid gas. Quicklime, when first made, is caustic and burning to the tongue, renders vegetable blues green, and is soluble in water; but when combined with carbonic acid it loses all these properties, its solubility, and its taste: it regains its power of effervescing, and becomes the same chemical substance as chalk or limestone.

Very few limestones or chalks consist entirely of lime and carbonic acid. The statuary marbles, or certain of the rhomboidal spars, are almost the only pure species; and the different properties of limestones, both as manures and cements, depend upon the nature of the ingredients mixed in the limestone; for the true calcareous element, the carbonate of lime, is uniformly the same in nature, properties, and effects, and consists of one proportion of carbonic acid 41·4, and one of lime 55.

When a limestone does not copiously effervesce in acids, and is sufficiently hard to scratch glass, it contains siliceous, and probably aluminous earth. When it is deep brown or red, or strongly coloured of any of the shades of brown or yellow, it contains oxide of iron. When it is not sufficiently hard to scratch glass, but effervesces slowly, and makes the acid in which it effervesces milky, it contains magnesia. And when it is black and emits a fetid smell if rubbed, it contains coally or bituminous matter.

The analysis of limestones is not a difficult matter; and the proportions of their constituent parts may be

easily ascertained by the processes described in the Lecture on the Analysis of Soils; and usually with sufficient accuracy for all the purposes of the farmer, by the fifth process.

Before any opinion can be formed of the manner in which the different ingredients in limestones modify their properties, it will be necessary to consider the operation of the pure calcareous element as a manure, and as a cement.

Quicklime in its pure state, whether in powder or dissolved in water, is injurious to plants. I have in several instances killed grass by watering it with lime-water. But lime, in its state of combination with carbonic acid, as is evident from the analyses given in the Fourth Lecture, is a useful ingredient in soils. Calcareous earth is found in the ashes of the greater number of plants; and exposed to the air lime cannot long continue caustic, for the reasons that were just now assigned, but soon becomes united to carbonic acid.

When newly burnt lime is exposed to air, it soon falls into powder; in this case it is called slacked lime; and the same effect is immediately produced by throwing water upon it, when it heats violently, and the water disappears.

Slacked-lime is merely a combination of lime with about one-third of its weight of water; *i. e.* 55 parts of lime absorb 17 parts of water; and in this case it is composed of a definite proportion of lime to a definite proportion of water, and is called by chemists *hydrate of lime;* and when hydrate of lime becomes carbonate of lime by long exposure to air, the water is expelled, and the carbonic acid gas takes its place.

When lime, whether freshly burnt or slacked, is mixed with any moist fibrous vegetable matter, there is a

strong action between the lime and the vegetable matter, and they form a kind of compost together, of which a part is usually soluble in water.

By this kind of operation, lime renders matter which was before comparatively inert nutritive; and as charcoal and oxygen abound in all vegetable matters, it becomes at the same time converted into carbonate of lime.

Mild lime, powdered limestone, marls or chalks, have no action of this kind upon vegetable matter; by their action they prevent the too rapid decomposition of substances already dissolved; but they have no tendency to form soluble matters.

It is obvious from these circumstances that the operation of quicklime, and marl or chalk, depends upon principles altogether different. Quicklime, in being applied to land, tends to bring any hard vegetable matter that it contains into a state of more rapid decomposition and solution, so as to render it a proper food for plants. Chalk, and marl, or carbonate of lime, will only improve the texture of the soil, or its relation to absorption; it acts merely as one of its earthy ingredients. Quicklime, when it becomes mild, operates in the same manner as chalk; but in the act of becoming mild, it prepares soluble out of insoluble matter.

It is upon this circumstance that the operation of lime in the preparation for wheat crops depends, and its efficacy in fertilizing peats, and in bringing into a state of cultivation all soils abounding in hard roots, or dry fibres, or inert vegetable matter.

The solution of the question, whether quicklime ought to be applied to a soil, depends upon the quantity of inert vegetable matter that it contains. The solu-

tion of the question, whether marl, mild lime, or powdered limestone, ought to be applied, depends upon the quantity of calcareous matter already in the soil. All soils are improved by mild lime, and ultimately by quicklime, which do not effervesce with acids; and sands more than clays.

When a soil, deficient in calcareous matter, contains much *soluble* vegetable manure, the application of quicklime should always be avoided, as it either tends to decompose the soluble matters by uniting to their carbon and oxygen so as to become mild lime, or it combines with the soluble matters, and forms compounds, having less attraction for water than the pure vegetable substance.

The case is the same with respect to most animal manures; but the operation of the lime is different in different cases, and depends upon the nature of the animal matter. Lime forms a kind of insoluble soap with oily matters, and then gradually decomposes them by separating from them oxygen and carbon. It combines likewise with the animal acids; and probably assists their decomposition by abstracting carbonaceous matter from them combined with oxygen; and consequently it must render them less nutritive. It tends to diminish likewise the nutritive powers of albumen from the same causes; and always destroys to a certain extent the efficacy of animal manures, either by combining with certain of their elements, or by giving to them new arrangements. Lime should never be applied with animal manures, unless they are too rich, or for the purpose of preventing noxious effluvia, as in certain cases mentioned in the last Lecture. It is injurious when mixed with any common dung, and tends to render the extractive matter insoluble.

I made an experiment on this subject: I mixed a quantity of the brown soluble extract, which was procured from sheep's dung, with five times its weight of quicklime. I then moistened them with water; the mixture heated very much; it was suffered to remain for 14 hours, and was then acted on by six or seven times its bulk of pure water; the water, after being passed through a filter, was evaporated to dryness; the solid matter obtained was scarcely coloured, and lime was mixed with a little saline matter.

In those cases in which fermentation is useful to produce nutriment from vegetable substances, lime is always efficacious. I mixed some moist tanner's spent bark with one-fifth of its weight of quicklime, and suffered them to remain together in a close vessel for three months; the lime had become coloured, and was effervescent;* when water was boiled upon the mixture, it gained a tint of fawn colour, and by evaporation furnished a fawn-coloured powder, which must have consisted of lime united to vegetable matter, for it burnt when strongly heated, and left a residuum of mild lime.

The limestones containing alumina and silica are less fitted for the purposes of manure than pure limestones; but the lime formed from them has no noxious quality. Such stones are less efficacious, merely because they furnish a smaller quantity of quicklime.

I mentioned bituminous limestones. There is very seldom any considerable portion of coally matter in

* [I have not found lime rendered effervescent on admixture with vegetable matter after two years, provided atmospheric air was completely excluded; vide note Vol. VII. p. 192., and the reference there given.]

these stones; never as much as five parts in 100; but such limestones make very good lime. The carbonaceous matter can do no injury to the land, and may, under certain circumstances, become a food of the plant, as is evident from what was stated in the last Lecture.

The subject of the application of the magnesian limestone is one of great interest.

It had been long known to farmers in the neighbourhood of Doncaster, that lime made from a certain limestone applied to the land often injured the crops considerably, as I mentioned in the Introductory Lecture. Mr. Tennant, in making a series of experiments upon this peculiar calcareous substance, found that it contained magnesia; and on mixing some calcined magnesia with soil in which he sowed different seeds, he found that they either died, or vegetated in a very imperfect manner, and the plants were never healthy. And with great justice and ingenuity he referred the bad effects of the peculiar limestone to the magnesian earth it contains.

In making some inquiries concerning this subject, I found that there were cases in which this magnesian limestone was used with good effect.

Amongst some specimens of limestone which Lord Somerville put into my hands, two marked as peculiarly good proved to be magnesian limestones. And lime made from the Breedon limestone is used in Leicestershire, where it is called hot lime; and I have been informed by farmers in the neighbourhood of the quarry, that they employ it advantageously in small quantities, seldom more than 25 or 30 bushels to the acre. And that they find it may be used with good effect in larger quantities upon rich land.

A minute chemical consideration of this question will lead to its solution.

Magnesia has a much weaker attraction for carbonic acid than lime, and will remain in the state of caustic or calcined magnesia for many months, though exposed to the air. And as long as any caustic lime remains, the magnesia cannot be combined with carbonic acid, for lime instantly attracts carbonic acid from magnesia.

When a magnesian limestone is burnt, the magnesia is deprived of carbonic acid, much sooner than the lime; and if there is not much vegetable or animal matter in the soil to supply by its decomposition carbonic acid, the magnesia will remain for a long while in the caustic state; and in this state acts as a poison to certain vegetables. And that more magnesian lime may be used upon rich soils, seems to be owing to the circumstance, that the decomposition of the manure in them supplies carbonic acid. And magnesia in its mild state, *i. e.* fully combined with carbonic acid, seems to be always a useful constituent of soils. I have thrown carbonate of magnesia (procured by boiling the solution of magnesia in super-carbonate of potassa) upon grass, and upon growing wheat and barley, so as to render the surface white; but the vegetation was not injured in the slightest degree. And one of the most fertile parts of Cornwall, the Lizard, is a district in which the soil contains mild magnesian earth.

The Lizard Downs bear a short and green grass, which feeds sheep, producing excellent mutton; and the cultivated parts are amongst the best corn lands in the county.

That the theory which I have ventured to give of the operation of magnesian lime is not unfounded, is shown

by an experiment which I made expressly for the purpose of determining the true nature of the operation of this substance. I took four portions of the same soil: with one I mixed $\frac{1}{20}$ of its weight of caustic magnesia, with another I mixed the same quantity of magnesia and a proportion of a fat decomposing peat equal to one-fourth of the weight of the soil. One portion of soil remained in its natural state: and another was mixed with peat without magnesia. The mixtures were made in December, 1806; and in April, 1807, barley was sown in all of them. It grew very well in the pure soil; but better in the soil containing the magnesia and peat, and nearly as well in the soil containing peat alone; but in the soil containing the magnesia alone it rose very feeble, and looked yellow and sickly.

I repeated this experiment, in the summer of 1810, with similar results; and I found that the magnesia in the soil, mixed with peat, became strongly effervescent, whilst the portion of the unmixed soil gave carbonic acid in much smaller quantities. In the one case, the magnesia had assisted in the formation of a manure, and had become mild; in the other case it had acted as a poison.

It is obvious, from what has been said, that lime from the magnesian limestone may be applied in large quantities to peats; and that where lands have been injured by the application of too large a quantity of magnesian lime, peat will be a proper and efficient remedy.

I mentioned that magnesian limestones effervesced little when plunged into an acid. A simple test of magnesia in a limestone is this circumstance, and its rendering diluted nitric acid, or aqua fortis, milky.

From the analysis of Mr. Tennant, it appears that the magnesian limestones contain from

20·3 to 22·5 magnesia.
29·5 to 31·7 lime.
47·2 carbonic acid.
0·8 clay and oxide of iron.

Magnesian limestones are usually coloured brown, or a pale yellow. They are found in Somersetshire, Leicestershire, Derbyshire, Shropshire, Durham, and Yorkshire. I have never met with any in other counties in England; but they abound in many parts of Ireland, particularly near Belfast.

The use of lime, as a cement, is not a proper subject for extensive discussion in a course of lectures on the chemistry of agriculture; yet as the theory of the operation of lime in this way is not fully stated in any elementary book that I have perused, I shall say a very few words on the applications of this part of chemical knowledge.

There are two modes in which lime acts as a cement; in its combination with water, and in its combination with carbonic acid.

The hydrate of lime has been already mentioned. When quicklime is rapidly made into a paste with water, it soon loses its softness, and the water and the lime form together a solid coherent mass, which consists, as has been stated before, of 17 parts of water to 55 parts of lime. When hydrate of lime, whilst it is consolidating, is mixed with red oxide of iron, alumina, or silica, the mixture becomes harder and more coherent than when lime alone is used; and it appears that this is owing to a certain degree of chemical attraction between hydrate of lime and these bodies; and they render it less liable to decompose by the action of the carbonic acid in the air, and less soluble in water.

The basis of all cements that are used for works which

are to be covered with water, must be formed from hydrate of lime; and the lime made from impure limestones answers this purpose very well. Puzzolana is composed principally of silica, alumina, and oxide of iron; and it is used mixed with lime, to form cements intended to be employed under water. Mr. Smeaton, in the construction of the Eddystone lighthouse, used a cement composed of equal parts by weight of slacked lime and puzzolana. Puzzolana is a decomposed lava. Tarras, which was formerly imported in considerable quantities from Holland, is a mere decomposed basalt: two parts of slacked lime, and one part of tarras, form the principal part of the mortar used in the great dykes of Holland. Substances which will answer all the ends of puzzolana and tarras, are abundant in the British islands. An excellent red tarras may be procured in any quantities from the Giant's Causeway in the north of Ireland; and decomposing basalt is abundant in many parts of Scotland, and in the northern districts of England in which coal is found.

Parker's cement, and cements of the same kind made at the alum works of Lord Dundas and Lord Mulgrave, are mixtures of calcined ferruginous, siliceous, and aluminous matter, with hydrate of lime.

The cements which act by combining with carbonic acid, or the common mortars, are made by mixing together slacked lime and sand. These mortars at first solidify as hydrates, and are slowly converted into carbonate of lime by the action of the carbonic acid of the air. Mr. Tennant found that a mortar of this kind, in three years and a quarter, had regained 63 per cent. of the quantity of carbonic acid gas which constitutes the definite proportion in carbonate of lime. The rubbish of mortar from houses owes its power to benefit lands

principally to the carbonate of lime it contains, and the sand in it; and its state of cohesion renders it particularly fitted to improve clayey soils.

The hardness of the mortar, in very old buildings, depends upon the perfect conversion of all its parts into carbonate of lime. The purest limestones are the best adapted for making this kind of mortar; the magnesian limestones make excellent water cements, but act with too little energy upon carbonic acid gas to make good common mortar.

The Romans, according to Pliny, made their best mortar a year before it was used; so that it was partially combined with carbonic acid gas before it was employed.

In burning lime there are some particular precautions required for the different kinds of limestones. In general, one bushel of coal is sufficient to make four or five bushels of lime. The magnesian limestone requires less fuel than the common limestone. In all cases in which a limestone containing much aluminous or siliceous earth is burnt, great care should be taken to prevent the fire from becoming too intense; for such lime easily vitrifies, in consequence of the affinity of lime for silica and alumina. And as in some places there are no other limestones than such as contain other earths, it is important to attend to this circumstance. A moderately good lime may be made at a low red heat; but it will melt into a glass at a white heat. In limekilns for burning such lime, there should be always a damper.

In general, when limestones are not magnesian, their purity will be indicated by their loss of weight in burning; the more they lose, the larger is the quantity of calcareous matter they contain. The magnesian lime-

stones contain more carbonic acid than the common limestones; and I have found all of them lose more than half their weight by calcination.

Besides being used in the forms of lime and carbonate of lime, calcareous matter is applied for the purposes of agriculture in other combinations. One of these bodies is *gypsum* or sulphate of lime. This substance consists of sulphuric acid (the same body that exists combined with water in oil of vitriol) and lime; and when dry it is composed of 55 parts of lime and 75 parts of sulphuric acid. Common gypsum or selenite, such as that found at Shotover Hill near Oxford, contains, besides sulphuric acid and lime, a considerable quantity of water; and its composition may be thus expressed:—

Sulphuric acid, one proportion -	75
Lime, one proportion - -	55
Water, two proportions - -	34

The nature of gypsum is easily demonstrated: if oil of vitriol be added to quicklime, there is a violent heat produced; when the mixture is ignited, water is given off, and gypsum alone is the result, if the acid has been used in sufficient quantity: and gypsum mixed with quicklime, if the quantity has been deficient. Gypsum free from water is sometimes found in nature, when it is called anhydrous selenite. It is distinguished from common gypsum by giving off no water when heated.

When gypsum, free from water, or deprived of water by heat, is made into a paste with water, it rapidly sets by combining with that fluid. Plaster of Paris is powdered dry gypsum,* and its property as a cement, and in its use in making casts, depends upon its solidifying a certain quantity of water, and making with it a coherent mass. Gypsum is soluble in about 500 times its

* Anhydrous gypsum.

weight of cold water, and is more soluble in hot water; so that when water has been boiled in contact with gypsum, crystals of this substance are deposited as the water cools. Gypsum is easily distinguished when dissolved by its properties of affording precipitates to solutions of oxalates and barytic salts.

Great difference of opinion has prevailed amongst agriculturists with respect to the uses of gypsum. It has been advantageously used in Kent, and various testimonies in favour of its efficacy have been laid before the Board of Agriculture by Mr. Smith. In America it is employed with signal success; but in most counties of England it has failed, though tried in various ways and upon different crops.

Very discordant notions have been formed as to the mode of operation of gypsum. It has been supposed by some persons to act by its power of attracting moisture from the air; but this agency must be comparatively insignificant. When *combined* with water, it retains that fluid too powerfully to yield it to the roots of the plant, and its adhesive attraction for moisture is inconsiderable; the small quantity in which it is used, likewise, is a circumstance hostile to this idea.

It has been said that gypsum assists the putrefaction of animal substances, and the decomposition of manure. I have tried some experiments on this subject, which are contradictory to the notion. I mixed some minced veal with about $\frac{1}{100}$ part of its weight of gypsum, and exposed some veal without gypsum under the same circumstances; there was no difference in the time in which they began to putrefy, and the process seemed to me most rapid in the case in which there was no gypsum present. I made other similar mixtures, employing in some cases larger and in some cases smaller

quantities of gypsum; and I used pigeons' dung in one instance instead of flesh, and with precisely similar results. It certainly in no case increased the rapidity of putrefaction.

Though it is not generally known, yet a series of experiments has been carried on for a great length of time in this country upon the operation of gypsum as a manure. The Berkshire and the Wiltshire peat-ashes contain a considerable portion of this substance. In the Newbury peat-ashes I have found from one-fourth to one-third of gypsum; and a larger quantity in some peat-ashes from the neighbourhood of Stockbridge: the other constituents of these ashes are calcareous, aluminous, and siliceous earth, with variable quantities of sulphate of potassa, a little common salt, and sometimes oxide of iron. The red ashes contain most of this last substance.

These peat-ashes are used as a top-dressing for cultivated grasses, particularly sainfoin and clover. In examining the ashes of sainfoin, clover, and rye grass, I found that they afforded considerable quantities of gypsum; and this substance, probably, is intimately combined as a necessary part of their woody fibre. If this be allowed, it is easy to explain the reason why it operates in such small quantities; for the whole of a clover crop, or sainfoin crop, on an acre, according to my estimation, would afford by incineration only three or four bushels of gypsum. In examining the soil in a field near Newbury, which was taken from below a footpath near the gate, where gypsum could not have been artificially furnished, I could not detect any of this substance in it; and at the very time I collected the soil, the peat-ashes were applied to the clover in the field. The reason why gypsum is not generally efficacious, is

probably because most cultivated soils contain it in sufficient quantities for the use of the grasses. In the common course of cultivation, gypsum is furnished in the manure; for it is contained in stable dung, and in the dung of all cattle fed on grass; and it is not taken up in corn crops, or crops of peas and beans, and in very small quantities in turnip crops; but where lands are exclusively devoted to pasturage and hay, it will be continually consumed. I have examined four different soils, cultivated by a series of common courses of crops, for gypsum. One was a light sand from Norfolk; another a clay, bearing good wheat, from Middlesex; the third a sand from Sussex; the fourth a clay from Essex. I found gypsum in all of them; and in the Middlesex soil it amounted nearly to one per cent. Lord Dundas informs me, that having tried gypsum without any benefit on two of his estates in Yorkshire, he was induced to have the soil examined for gypsum, according to the process described in the Fourth Lecture, and this substance was found in both the soils.

Should these statements be confirmed by future inquiries, a practical inference of some value may be derived from them. It is possible that lands which have ceased to bear good crops of clover, or artificial grasses, may be restored by being manured with gypsum. I have mentioned that this substance is found in Oxfordshire; it is likewise abundant in many other parts of England; in Gloucestershire, Somersetshire, Derbyshire, Yorkshire, &c.; and requires only pulverization for its preparation.

Some very interesting documents upon the use of sulphate of iron or green vitriol, which is a salt produced from peat in Bedfordshire, have been laid before the Board by Dr. Pearson; and I have witnessed the

fertilizing effects of a ferruginous water used for irrigating a grass meadow made by the Duke of Manchester, at Priestley Bog, near Woburn, an account of the produce of which has been published by the Board of Agriculture. I have no doubt that the peat salt and the vitriolic water acted chiefly by producing gypsum.

The soils on which both are efficacious are calcareous; and sulphate of iron is decomposed by the carbonate of lime in such soils. The sulphate of iron consists of sulphuric acid and oxide of iron, and is an acid and a very soluble salt: when a solution of it is mixed with carbonate of lime, the sulphuric acid quits the oxide of iron to unite to the lime, and the compounds produced are insipid and comparatively insoluble.

I collected some of the deposition from the ferruginous water on the soil in Priestley Meadow. I found it consisted of gypsum, carbonate of iron, and insoluble sulphate of iron. The principal grasses in Priestley Meadow are, meadow fox-tail, cock's-foot, meadow fescue, fiorin, and sweet-scented vernal grass. I have examined the ashes of three of these grasses, meadow fox-tail, cock's-foot, and fiorin. They contained a considerable proportion of gypsum.

Vitriolic impregnations, in soils where there is no calcareous matter, as in a soil from Lincolnshire, to which I referred in the Fourth Lecture, are injurious; but it is probably in consequence of their supplying an excess of ferruginous matter to the sap. Oxide of iron in small quantities forms a useful part of soils; and as is evident from the details in the Third Lecture, it is found in the ashes of plants; and, probably, is hurtful only in its acid combinations.

I have just mentioned certain peats, the ashes of which afford gypsum; but it must not be inferred from

this that all peats agree with them. I have examined various peat-ashes from Scotland, Ireland, Wales, and the northern and western parts of England, which contained no quantity that could be useful; and these ashes abound in siliceous, aluminous earths, and oxide of iron.

Lord Charleville found in some peat-ashes from Ireland sulphate of potassa, *i. e.* the sulphuric acid combined with potassa.

Vitriolic matter is usually formed in peats; and if the soil or substratum is calcareous, the ultimate result is the production of gypsum. In general, when a recent peat-ash emits a strong smell resembling that of rotten eggs when acted upon by vinegar, it will furnish gypsum.

Phosphate of lime is a combination of phosphoric acid and lime, one proportion of each. It is a compound insoluble in pure water, but soluble in water containing any acid matter. It forms the greatest part of calcined bones. It exists in most excrementitious substances, and is found both in the straw and grain of wheat, barley, oats, and rye, and likewise in beans, peas, and tares. It exists in some places in these islands native; but only in very small quantities. Phosphate of lime is generally conveyed to the land in the composition of other manure; and it is probably necessary to corn crops and other white crops.

Bone-ashes ground to powder will probably be found useful on arable lands containing much vegetable matter, and may perhaps enable soft peats to produce wheat; but the powdered bone in an uncalcined state is much to be preferred in all cases when it can be procured.

The *saline compounds of magnesia* will require very little discussion as to their uses as manures. The most

important relations of this subject to agriculture have been considered in the former part of this Lecture, when the application of the magnesian limestone was examined. In combination with sulphuric acid magnesia forms a soluble salt. This substance, it is stated by some inquirers, has been found of use as a manure; but it is not found in nature in sufficient abundance, nor is it capable of being made artificially sufficiently cheap to be of useful application in the common course of husbandry.

Wood ashes consist principally of the vegetable alkali united to carbonic acid; and as this alkali is found in almost all plants, it is not difficult to conceive that it may form an essential part of their organs. The general tendency of the alkalies is to give solubility to vegetable matters; and in this way they may render carbonaceous and other substances capable of being taken up by the tubes in the radicle fibres of plants. The vegetable alkali, likewise, has a strong attraction for water, and even in small quantities, may tend to give a due degree of moisture to the soil, or other manures; though this operation, from the small quantities used, or existing in the soil, can be only of a secondary kind.

The *mineral alkali*, or *soda*, is found in the ashes of sea-weed, and may be procured by certain chemical agencies from *common salt*. Common salt consists of the metal named sodium, combined with chlorine; and pure soda consists of the same metal united to oxygen. When water is present which can afford oxygen to the sodium, soda may be obtained in several modes from salt.

The same reasoning will apply to the operation of the pure mineral alkali, or the carbonated alkali, as to that of the vegetable alkali; and when common salt acts as a

manure, it is probably by entering into the composition of the plant in the same manner as gypsum, phosphate of lime, and the alkalies. Sir John Pringle has stated that salt, in small quantities, assists the decomposition of animal and vegetable matter. This circumstance may render it useful in certain soils. Common salt, likewise, is offensive to insects. That in small quantities it is sometimes a useful manure, I believe, is fully proved; and it is probable that its efficacy depends upon many combined causes.

Some persons have argued against the employment of salt, because, when used in large quantities, it either does no good, or renders the ground sterile; but this is a very unfair mode of reasoning. That salt in large quantities rendered land barren, was known long before any records of agricultural science existed. We read in the Scriptures, that Abimelech took the city of Shechem, "and beat down the city, and sowed it with salt," that the soil might be for ever unfruitful. Virgil reprobates a salt soil; and Pliny, though he recommends giving salt to cattle, yet affirms, that when strewed over land, it renders it barren. But these are not arguments against a proper application of it. Refuse salt in Cornwall, which, however, likewise contains some of the oil and exuviæ of fish, has long been known as an admirable manure. And the Cheshire farmers contend for the benefit of the peculiar produce of their country.

It is not unlikely that the same causes influence the effects of salt as those which act in modifying the operation of gypsum. Most lands in this island, particularly those near the sea, probably contain a sufficient quantity of salt for all the purposes of vegetation; and in such cases the supply of it to the soil will not only be useless, but may be injurious. In great storms the

spray of the sea has been carried more than fifty miles from the shore; so that from this source salt must be often supplied to the soil. I have found salt in all the sandstone rocks that I have examined, and it must exist in the soil derived from these rocks. It is a constituent, likewise, of almost every kind of animal and vegetable manure.

Besides these compounds of the alkaline earths and alkalies, many others have been recommended for the purpose of increasing vegetation; such as *nitre,* or the nitrous acid combined with potassa. Sir Kenelm Digby states, that he made barley grow very luxuriantly by watering it with a very weak solution of nitre; but he is too speculative a writer to awaken confidence in his results. This substance consists of one proportion of azote, six of oxygen, and one of potassium; and it is not unlikely that it may furnish azote to form albumen or gluten in those plants that contain them; but the nitrous salts are too valuable for other purposes to be used as manures.

Dr. Home states that *sulphate of potassa,* which, as I just now mentioned, is found in the ashes of some peats, is a useful manure. But Mr. Naismith* questions his results; and quotes experiments hostile to his opinion, and, as he conceives, unfavourable to the efficacy of any species of saline manure.

Much of the discordance of the evidence relating to the efficacy of saline substances depends upon the circumstance of their having been used in different proportions, and in general in quantities much too large.

I made a number of experiments in May and June, 1807, on the effects of different saline substances on barley and on grass growing in the same garden, the

* Elements of Agriculture, p. 78.

soil of which was a light sand, of which 100 parts were composed of 60 parts of siliceous sand, and 24 parts finely divided matter, consisting of 7 parts carbonate of lime, 12 parts alumina and silica, less than one part saline matter, principally common salt, with a trace of gypsum and sulphate of magnesia: the remaining 16 parts were vegetable matter.

The solutions of the saline substances were used twice a week, in the quantity of two ounces, on spots of grass and corn, sufficiently remote from each other to prevent any interference of results. The substances tried were *super-carbonate, sulphate, acetate, nitrate*, and *muriate of potassa; sulphate of soda, sulphate, nitrate, muriate*, and *carbonate of ammonia.* I found that in all cases when the quantity of the salt equalled $\frac{1}{30}$ part of the weight of the water, the effects were injurious; but least so in the instances of the carbonate, sulphate, and muriate of ammonia. When the quantities of the salts were $\frac{1}{300}$ part of the solution, the effects were different. The plants watered with the solutions of the sulphates grew just in the same manner as similar plants watered with rain water. Those acted on by the solution of nitre, acetate, and supercarbonate of potassa, and muriate of ammonia, grew rather better. Those treated with the solution of carbonate of ammonia grew most luxuriantly of all. This last result is what might be expected, for carbonate of ammonia consists of carbon, hydrogen, azote, and oxygen. There was, however, another result which I had not anticipated—the plants watered with solution of nitrate of ammonia did not grow better than those watered with rain water. The solution reddened litmus paper; and probably the free acid exerted a prejudicial effect, and interfered with the result.

Soot doubtless owes a part of its efficacy to the am-

moniacal salt it contains. The liquor produced by the distillation of coal contains carbonate and acetate of ammonia, and is said to be a very good manure.

In 1808, I found the growth of wheat in a field at Roehampton assisted by a very weak solution of acetate of ammonia.

Soapers' waste has been recommended as a manure, and it has been supposed that its efficacy depended upon the different saline matters it contains; but their quantity is very minute, indeed, and its principal ingredients are mild lime and quicklime. In the soapers' waste from the best manufactories, there is scarcely a trace of alkali. Lime moistened with sea-water affords more of this substance, and is said to have been used in some cases with more benefit than common lime.

Mr. Knight informs me, that he has found, in the two last seasons, that pond mud, of very poor quality, chiefly clay, having been mixed with coal dust, to afford fuel for his hot-houses, afforded a manure of considerable power. It acts, however, much more beneficially upon soils which are in tolerably good condition, and perhaps rather stimulates than feeds; for on very poor soil, where some was laid in the last winter, its effects can scarcely be perceived.

It is unnecessary to discuss to any greater extent the effects of saline substances on vegetation; except the ammoniacal compounds, or the compounds containing nitric, acetic, and carbonic acid, none of them can afford by their decomposition any of the common principles of vegetation, carbon, hydrogen, and oxygen.

The alkaline sulphates and the earthy muriates are so seldom found in plants, or are found in such minute quantities, that it can never be an object to apply them to the soil. It was stated in the beginning of this Lec-

ture, that the earthy and alkaline substances seem never to be formed in vegetation; and there is every reason likewise to believe that they are never decomposed; for after being absorbed they are found in their ashes.

The metallic bases of them cannot exist in contact with aqueous fluids; and these metallic bases, like other metals, have not as yet been resolved into any other forms of matter by artificial processes: they combine readily with other elements; but they remain indestructible, and can be traced undiminished in quantity through their diversified combinations.

LECTURE VIII.

On the Improvement of Lands by Burning; Chemical Principles of this Operation.—On Irrigation and its Effects.—On Fallowing; its Disadvantages and Uses.—On the Convertible Husbandry founded on Regular Rotations of Different Crops.—On Pasture; Views connected with its Application.—On Various Agricultural Objects connected with Chemistry.—Conclusion.

The improvement of sterile lands by burning was known to the Romans. It is mentioned by Virgil in the first book of the Georgics: "Sæpe etiam steriles incendere profuit agros." It is a practice still much in use in many parts of these islands; the theory of its operation has occasioned much discussion, both among scientific men and farmers. It rests entirely upon chemical doctrines; and I trust I shall be able to offer you satisfactory elucidations on the subject.

The bases of all common soils, as I stated in the Fourth Lecture, are mixtures of the primitive earths and oxide of iron; and these earths have a certain degree of attraction for each other. To regard this attraction in its proper point of view, it is only necessary to consider the composition of any common siliceous stone. Feldspar, for instance, contains siliceous, aluminous, calcareous earths, fixed alkali, and oxide of iron, which exist in one compound, in consequence of their chemical attractions for each other. Let this stone be ground into impalpable powder, it then becomes a substance like clay: if the powder be heated very strongly it fuses, and on cooling forms a coherent mass similar

to the original stone; the parts separated by mechanical division adhere again in consequence of chemical attraction. If the powder is heated less strongly the particles only superficially combine with each other, and form a gritty mass, which, when broken into pieces, has the characters of sand.

If the power of the powdered feldspar to absorb water from the atmosphere, before and after the application of the heat be compared, it is found much less in the last case.

The same effect takes place, when the powder of other siliceous or aluminous stones, is made the subject of experiment.

I found that two equal portions of basalt ground into impalpable powder, of which one had been strongly ignited, and the other exposed only to a temperature equal to that of boiling water, gained very different weights in the same time when exposed to air. In four hours the one had gained only two grains, whilst the other had gained seven grains.

When clay or tenacious soils are burnt, the effect is of the same kind; they are brought nearer to a state analogous to that of sands.

In the manufacture of bricks, the general principle is well illustrated; if a piece of dry brick earth be applied to the tongue, it will adhere to it very strongly, in consequence of its power to absorb water; but after it has been burnt, there will be scarcely a sensible adhesion.

The process of burning renders the soil less compact, less tenacious and retentive of moisture; and when properly applied, may convert a matter that was stiff, damp, and in consequence cold, into one powdery, dry, and warm; and much more proper as a bed for vegetable life.

The great objection made by speculative chemists to

paring and burning is, that it destroys vegetable and animal matter, or the manure in the soil; but in cases in which the texture of its earthy ingredients is permanently improved, there is more than a compensation for this temporary disadvantage. And, in some soils, where there is an excess of inert vegetable matter, the destruction of it must be beneficial; and the carbonaceous matter remaining in the ashes, may be more useful to the crop, than the vegetable fibre from which it was produced.

I have examined, by a chemical analysis, three specimens of ashes, from different lands that had undergone paring and burning. The first was a quantity sent to the Board by Mr. Boys, of Bellhanger, in Kent, whose treatise on paring and burning has been published. They were from a chalk soil, and 200 grains contained

80 Carbonate of lime.
11 Gypsum.
9 Charcoal.
15 Oxide of iron.
3 Saline matter; viz., sulphate of potash, muriate of magnesia, with a minute quantity of vegetable alkali.

The remainder alumina and silica.

Mr. Boys estimates that 2660 bushels are the common produce of an acre of ground, which, according to his calculation, would give 172900 lbs., containing

Carbonate of lime - -	69160 lbs.
Gypsum - - -	9509·5
Oxide of iron - -	12967·5
Saline matter - - -	2593·5
Charcoal - - -	7780·5

In this instance there was undoubtedly a very considerable quantity of matter capable of being active as

manure produced in the operation of burning. The charcoal was very finely divided; and, exposed on a large surface on the field, must have been gradually converted into carbonic acid. And gypsum and oxide of iron, as I mentioned in the last Lecture, seem to produce the very best effects, when applied to lands containing an excess of carbonate of lime.

The second specimen was from a soil near Coleorton, in Leicestershire, containing only four per cent. of carbonate of lime, and consisting of three-fourths light siliceous sand, and about one-fourth clay. This had been turf before burning, and 100 parts of the ashes gave

6 Parts charcoal.
3 Muriate of soda, and sulphate of potash, with a trace of vegetable alkali.
9 Oxide of iron.

And the remainder the earths.

In this instance, as in the other, finely-divided charcoal was found; the solubility of which would be increased by the presence of the alkali.

The third instance was that of a stiff clay, from Mount's Bay, Cornwall. This land had been brought into cultivation from a heath by burning, about ten years before; but having been neglected, furze was springing up in different parts of it, which gave rise to the second paring and burning: 100 parts of the ashes contained

8 Parts of charcoal.
2 Of saline matter, principally common salt, with a little vegetable alkali.
7 Oxide of iron.
2 Carbonate of lime.

Remainder alumina and silica.

Here the quantity of charcoal was greater than in the other instances. The salt, I suspect, was owing to the

vicinity of the sea, it being but two miles off. In this land, there was certainly an excess of dead vegetable fibre, as well as unprofitable living vegetable matter; and I have since heard that a great improvement took place.

Many obscure causes have been referred to, for the purpose of explaining the effects of paring and burning; but I believe they may be referred entirely to the diminution of the coherence and tenacity of clays, and to the destruction of inert and useless vegetable matter, and its conversion into a manure.

Dr. Darwin, in his Phytologia, has supposed that clay during torrefaction may absorb some nutritive principles from the atmosphere, that afterwards may be supplied to plants; but the earths are pure metallic oxides, saturated with oxygen; and the tendency of burning is to expel any other volatile principles that they may contain in combination. If the oxide of iron in soils, is not saturated with oxygen, torrefaction tends to produce its further union with this principle; and hence in burning the colour of clays changes to red. The oxide of iron, containing its full proportion of oxygen, has less attraction for acids, than the other oxide, and is consequently less likely to be dissolved by any fluid acid in the soil; and it appears in this state to act in the same manner as the earths. A very ingenious author, whom I quoted at the end of the last Lecture, supposes that the oxide of iron, when combined with carbonic acid, is poisonous to plants, and that one use of torrefaction is to expel the carbonic acid from it; but the carbonate of iron is not soluble in water, and is a very inert substance; and I have raised a luxuriant crop of cresses in a soil composed of one-fifth carbonate of iron, and four-fifths carbonate of lime. Carbonate of iron abounds in some of the most fertile soils in England, particularly the red hop soil.

And there is no theoretical ground for supposing that carbonic acid, which is an essential food of plants, should in any of its combinations be poisonous to them; and it is known that lime and magnesia are both noxious to vegetation, unless combined with this principle.

All soils that contain too much dead vegetable fibre, and which consequently lose from one-third to one-half of their weight by incineration, and all such as contain their earthy constituents in an impalpable state of division, *i. e.* the stiff clays and marls, are improved by burning; but in coarse sands, or rich soils, containing a just mixture of the earths, and in all cases in which the texture is already sufficiently loose, or the organizable matter sufficiently soluble, the process of torrefaction cannot be useful.

All poor siliceous sands must be injured by it; and here practice is found to accord with theory. Mr. Young, in his Essay on Manures, states "that he found burning injure sand;" and the operation is never performed by good agriculturists upon siliceous sandy soils, after they have once been brought into cultivation.

An intelligent farmer in Mount's Bay, told me that he had pared and burned a small field several years ago, which he had not been able to bring again into good condition. I examined the spot; the grass was very poor and scanty, and the soil an arid siliceous sand.

Irrigation, or *watering land*, is a practice which, at first view, appears the reverse of torrefaction; and in general, in nature, the operation of water is to bring earthy substances into an extreme state of division. But in the artificial watering of meadows, the beneficial effects depend upon many different causes—some chemical, some mechanical.

Water is absolutely essential to vegetation; and when land has been covered by water in the winter, or in the beginning of spring, the moisture that has penetrated deep into the soil, and even the sub-soil, becomes a source of nourishment to the roots of the plant in the summer, and prevents those bad effects that often happen in lands in their natural state, from a long continuance of dry weather.

When the water used in irrigation has flowed over a calcareous country, it is generally found impregnated with carbonate of lime; and in this state it tends, in many instances, to ameliorate the soil.

Common river-water, also, generally contains a certain portion of organizable matter, which is much greater after rains than at other times; and which exists in the largest quantity when the stream rises in a cultivated country.

Even in cases when the water used for flooding is pure, and free from animal or vegetable substances, it acts by causing the more equable diffusion of nutritive matter existing in the land; and in very cold seasons it preserves the tender roots and leaves of the grass from being affected by frost.

Water is of greater specific gravity at 42° Fahrenheit, than at 32°, the freezing point; and hence in a meadow irrigated in winter, the water immediately in contact with the grass is rarely below 40°, a degree of temperature not at all prejudicial to the living organs of plants.

In 1804, in the month of March, I examined the temperature in a water meadow near Hungerford, in Berkshire, by a very delicate thermometer. The temperature of the air at seven in the morning was 29°. The water was frozen above the grass. The tempera-

ture of the soil below the water in which the roots of the grass were fixed was 43°.

In general those waters which breed the best fish are the best fitted for watering meadows; but most of the benefits of irrigation may be derived from any kind of water. It is, however, a general principle, that waters containing ferruginous impregnations, though possessed of fertilizing effects, when applied to a calcareous soil, are injurious on soils that do not effervesce with acids; and that calcareous waters, which are known by the earthy deposit they afford when boiled, are of most use on siliceous soils, or other soils containing no remarkable quantity of carbonate of lime.

The most important processes for improving land are those which have been already discussed, and that are founded upon the circumstance of removing certain constituents from the soil, or adding others, or changing their nature; but there is an operation of very ancient practice still much employed, in which the soil is exposed to the air, and submitted to processes which are purely mechanical, namely, *fallowing.*

The benefits arising from fallows have been much over-rated. A summer fallow, or a clean fallow, may be sometimes necessary in lands overgrown with weeds, particularly if they are lands which cannot be pared and burnt with advantage; but is certainly unprofitable as part of a general system in husbandry.

It has been supposed by some writers, that certain principles necessary to fertility are derived from the atmosphere, which are exhausted by a succession of crops, and that these are again supplied during the repose of the land, and the exposure of the pulverized soil to the influence of the air; but this, as was mentioned in the introductory Lecture, is not a correct

statement. Oxygen is absorbed by the vegetable film, and, perhaps, in certain cases, azote; but the earths, the great elements of soils, cannot be combined with new elements from the air; none of them unite to azote; and such of them as are capable of attracting carbonic acid are always saturated with it in those soils on which the practice of fallowing is adopted. The vague ancient opinion of the use of nitre, and of nitrous salts in vegetation, seems to have been one of the principal speculative reasons for the defence of summer fallows. Nitrous salts are produced during the exposure of soils containing vegetable and animal remains, and in greatest abundance in hot weather; but it is probably by the combination of azote from these remains with oxygen in the atmosphere that the acid is formed, and at the expense of an element which otherwise would have formed ammonia; the compounds of which, as is evident from what is stated in the last Lecture, are much more efficacious than the nitrous compounds in assisting vegetation.

When weeds are buried in the soil, by their absorption of oxygen and gradual decomposition they furnish a certain quantity of soluble matter, and a soil will certainly in consequence produce better crops at the end of a fallow; but the use of this practice must depend upon the quantity of vegetable fibre and its nature, and upon the quality of the soil. Carbonic acid gas is formed during the whole time by the action of the vegetable matter upon the oxygen of the air, and the greater part of it is lost to the soil in which it is formed, and dissipated in the atmosphere.

The action of the sun upon the surface of the soil tends to disengage the gaseous and the volatile fluid matters that it contains; and heat increases the rapidity

of fermentation: and in the summer fallow nourishment is rapidly produced, at a time when no vegetables are present capable of absorbing it.

Land, when it is not employed in preparing food for animals, should be applied to the purpose of the preparation of manure for plants; and this is effected by means of green crops, in consequence of the absorption of carbonaceous matter in the carbonic acid of the atmosphere. In a summer's fallow a period is always lost in which vegetables may be raised, either as food for animals, or as nourishment for the next crop; and the texture of the soil is not so much improved by its exposure as in winter, when the expansive powers of ice, the gradual dissolution of snows, and the alternations from wet to dry, tend to pulverize it, and to mix its different parts together.

In the drill husbandry the land is preserved clean by the extirpation of the weeds by hand, and by raising the crops in rows, which renders the destruction of the weeds much more easy. Manure is supplied either by the green crops themselves, or from the dung of the cattle fed upon them; and the plants having large systems of leaves are made to alternate with those bearing grain.

It is a great advantage in the convertible system of cultivation, that the whole of the manure is employed; and that those parts of it which are not fitted for one crop remain as nourishment for another. Thus, in Mr. Coke's course of crops, the turnip is the first in the order of succession; and this crop is manured with recent dung, which immediately affords sufficient soluble matter for its nourishment; and the heat produced in fermentation assists the germination of the seed and the growth of the plant. After turnips, barley with

grass seeds is sown; and the land, having been little exhausted by the turnip crop, affords the soluble parts of the decomposing manure to the grain. The grasses, rye-grass, and clover remain, which derive a small part only of their organized matter from the soil, and probably consume the gypsum in the manure, which would be useless to other crops: these plants, likewise, by their large systems of leaves, absorb a considerable quantity of nourishment from the atmosphere; and when ploughed in at the end of two years, the decay of their roots and leaves affords manure for the wheat crop; and at this period of the course, the woody fibre of the farm-yard manure, which contains the phosphate of lime and the other difficultly soluble parts, is broken down; and as soon as the most exhausting crop is taken, recent manure is again applied.

Mr. Gregg, whose ingenious system of cultivation has been published by the Board of Agriculture, and who has the merit of first adopting a plan similar to Mr. Coke's upon strong clays, suffers the ground after barley to remain at rest for two years in grass: sows peas and beans on the leys: ploughs in the pea or bean stubble for wheat; and in some instances follows his wheat crops by a course of winter tares and winter barley, which is eat off in the spring, before the land is sowed for turnips.

Peas and beans, in all instances, seem well adapted to prepare the ground for wheat; and in some rich lands, as in the alluvial soil of the Parret, mentioned in the Fourth Lecture, and at the foot of the South Downs in Sussex, they are raised in alternate crops for years together. Peas and beans contain, as appears from the analyses in the Third Lecture, a small quantity of matter analogous to albumen; but it seems that the

azote, which forms a constituent part of this matter, is derived from the atmosphere. The dry bean leaf, when burnt, yields a smell approaching to that of decomposing animal matter; and in its decay in the soil may furnish principles capable of becoming a part of the gluten in wheat.

In considering what vegetables are likely to be profitable on a particular *soil*, it is necessary always to attend, not only to the mean temperature of the climate, but likewise to the summer's heat and winter's cold. Thus, maize, or Indian corn, and the vine, require a very hot summer; and the olive would be destroyed by our winter. It is unnecessary, therefore, to say any thing of these plants, or similar plants, in relation to a British system of cultivation: but, in some of our colonies, particularly the Cape of Good Hope, almost all the vegetable productions of Italy, Portugal, or Spain, are or may be raised. The wines of the Cape may be doubtless improved by a proper selection of soils, and by employing peasants from the vine countries of France in cultivating the grape, and in the manufacture of wine. The flavour of the juice of the grape changes as the soil is different; and in the selecting a place for a vineyard, much may be gained by analysis or chemical examination of the soil, and by comparing it with the best soils of the best wine provinces of France, Germany, and Spain. This is a subject not unworthy the attention of our government.

Though the general composition of plants is very analogous, yet the specific difference in the products of many of them, and the facts stated in the last lecture, prove that they must derive different materials from the soil; and though the vegetables having the smallest systems of leaves will proportionably most exhaust the

soil of common nutritive matter, yet particular vegetables, when their produce is carried off, will require peculiar principles to be supplied to the land in which they grow. Strawberries and potatoes at first produce luxuriantly in virgin mould recently turned up from pasture; but in a few years they degenerate, and require a fresh soil; and the organization of these plants is such, as to be constantly producing the migration of their layers: thus the strawberry by its long shoots is constantly endeavouring to occupy a new soil; and the fibrous radicles of the potatoe produce bulbs at a considerable distance from the parent plant. Lands in a course of years often cease to afford good cultivated grasses: they become (as it is popularly said) tired of them; and one of the probable reasons for this was stated in the last lecture.

The most remarkable instance of the powers of vegetables to exhaust the soil of certain principles necessary to their growth is found in certain funguses. Mushrooms are said never to rise in two successive seasons on the same spot, and the production of the phenomena called fairy rings has been ascribed by Dr. Wollaston to the power of the peculiar fungus which forms it to exhaust the soil of the nutriment necessary for the growth of the species. The consequence is, that the ring annually extends, for no seeds will grow where their parents grew before them, and the interior part of the circle has been exhausted by preceding crops; but where the fungus has died, nourishment is supplied for grass, which usually rises within the circle, coarse, and of a dark green colour.

When cattle are fed upon land not benefited by their manure, the effect is always an exhaustion of the soil; this is particularly the case where carrying horses are

kept on estates; they consume the pasture during the night, and drop the greatest part of their manure during their labour in the day-time.

The exportation of grain from a country, unless some articles capable of becoming manure are introduced in compensation, must ultimately tend to exhaust the soil. Some of the spots now desert sands in northern Africa, and Asia Minor, were anciently fertile. Sicily was the granary of Italy; and the quantity of corn carried off from it by the Romans is probably a chief cause of its present sterility. In this island, our commercial system at present has the effect of affording substances, which in their use and decomposition must enrich the land. Corn, sugar, tallow, oil, skins, furs, wine, silk, cotton, &c., are imported, and fish are supplied from the sea. Amongst our numerous exports, woollen and linen, and leather goods are almost the only substances which contain any nutritive materials derived from the soil.

In all courses of crops it is necessary that every part of the soil should be made as useful as possible to the different plants; but the depth of the furrow in ploughing must depend upon the nature of the soil, and of the subsoil. In rich clayey soils the furrow can scarcely be too deep; and even in sands, unless the subsoil contains some principles noxious to vegetables, the same practice should be adopted. When the roots are deep, they are less liable to be injured, either by excess of rain, or drought; the layers shoot forth their radicles into every part of the soil; and the space from which the nourishment is derived is more considerable, than when the seed is superficially inserted in the soil.

There has been much difference of opinion with respect to permanent pasture; but the advantages or disadvantages can only be reasoned upon according to

the circumstances of situation and climate. Under the circumstances of irrigation, lands are extremely productive, with comparatively little labour; and in climates where great quantities of rain fall the natural irrigation produces the same effects as artificial. When hay is in great demand, as sometimes happens in the neighbourhood of the metropolis, where manure can be easily procured, the application of it to pasture is repaid by the increase of crop; but top-dressing grass land with animal or vegetable manure cannot be recommended as a general system. Dr. Coventry very justly observes, that there is greater waste of the manure in this case than when it is ploughed into the soil for seed crops. The loss by exposure to the air and the sunshine offers reasons, in addition to those that have been already quoted in the Sixth Lecture, for the application of manure even in this case, in a state of incipient and not completed fermentation.

Very little attention has been paid to the nature of the grasses best adapted for permanent pasture. The chief circumstance which gives value to a grass is the quantity of nutritive matter that the whole crop will afford; but the time and duration of its produce are likewise points of great importance; and a grass that supplies green nutriment throughout the whole of the year may be more valuable than a grass which yields its produce only in summer, though the whole quantity of food supplied by it should be much less.

The grasses that propagate themselves by layers, the different species of Agrostis, supply pasture throughout the year; and, as it has been mentioned on a former occasion, the concrete sap stored up in their joints renders them a good food even in winter. I saw four square yards of fiorin grass cut in the end of January,

this year, in a meadow exclusively appropriated to the cultivation of fiorin, by the Countess of Hardwicke, the soil of which is a damp stiff clay. They afforded 28 pounds of fodder; of which 1000 parts afforded 64 parts of nutritive matter, consisting nearly of one-sixth of sugar, and five-sixths of mucilage, with a little extractive matter. In another experiment, four square yards gave 27 pounds of grass. The quality of this grass is inferior to that of the fiorin referred to in the table in the latter part of the Third Lecture, which was cultivated by Sir Joseph Banks in Middlesex, in a much richer soil, and cut in December.

The fiorin grass, to be in perfection, requires a moist climate, or a wet soil; and it grows luxuriantly in cold clays unfitted for other grasses. In light sands and dry situations its produce is much inferior as to quantity and quality.

The common grasses, properly so called, that afford most nutritive matter in early springs, are the vernal meadow grass and meadow fox-tail grass; but their produce, at the time of flowering and ripening the seed, is inferior to that of a great number of other grasses; their latter-math is, however, abundant.

Tall fescue grass stands highest, according to the experiments of the Duke of Bedford, of any grass properly so called, as to the quantity of nutritive matter afforded by the whole crop, when cut at the time of flowering; and meadow cat's-tail grass affords most food when cut at the time the seed is ripe; the highest latter-math produce of the grasses examined in the Duke of Bedford's experiments is from the sea-meadow grass.

Nature has provided, in all permanent pastures, a mixture of various grasses, the produce of which differs at different seasons. Where pastures are to be made ar-

tificially, such a mixture ought to be imitated: and, perhaps, pastures superior to the natural ones may be made by selecting due proportions of those species of grasses fitted for the soil which affords respectively the greatest quantities of spring, summer, latter-math, and winter produce. A reference to the details in the Appendix will show that such a plan of cultivation is very practicable.

The propagation of grasses, by layers, has lately given rise to a considerable improvement in the formation of pasture, by what has been called inoculation. A certain portion of old pasture is removed with the roots of the grasses and a part of the soil, and planted (as it were) in arable land at certain intervals. By the spreading of the layers, a surface of grasses is speedily formed; and the old pasture, if too much of it be not removed, soon recovers itself, in consequence of the operation of the same principle. This improvement has arisen in the same place where agriculture has so long been an object of unremitted and patriotic exertions. Mr. Coke's steward is the author.

In all lands, whether arable or pasture, weeds of every description should be rooted out before the seed is ripe; and if they are suffered to remain in hedge-rows, they should be cut when in flower, or before, and made into heaps for manure; in this case they will furnish more nutritive matter in their decomposition; and their increase, by the dispersion of seeds, will be prevented. The farmer, who suffers weeds to remain till their ripe seeds are shed, and scattered by the winds, is not only hostile to his own interests, but is likewise an enemy to the public; a few thistles neglected soon will stock a farm; and by the light down which is attached to their seeds, they may be distributed over a whole coun-

try. Nature has provided such ample resources for the continuance of even the meanest vegetable tribes, that it is very difficult to insure the destruction of such as are hostile to the agriculturist, even with every precaution. Seeds excluded from the air will remain for years inactive in the soil,* and yet germinate under favourable circumstances; and the different plants, the seeds of which, like those of the thistle and dandelion, are furnished with beards or wings, may be brought from an immense distance. The fleabane of Canada has only lately been found in Europe; and Linnæus supposes that it has been transported from America, by the very light downy plumes with which the seed is provided.

In feeding cattle with green food, there are many advantages in *soiling*, or supplying them with food, where their manure is preserved, out of the field: the plants are less injured when cut than when torn or jagged by the teeth of the cattle, and no food is wasted by being trodden down. They are likewise obliged to feed without making selection; and in consequence the whole food is consumed: the attachment or dislike to a particular kind of food exhibited by animals, offers no proof of its nutritive powers. Cattle, at first, refuse lin-

* The appearance of seeds in places where their parent plants are not found may be easily accounted for from this circumstance, and other circumstances. Many seeds are carried from island to island by currents in the sea, and are defended by their hard coats from the immediate action of the water. West Indian seeds (of this description) are often found on our coasts, and readily germinate; their long voyage having been barely sufficient to afford the cotyledon its due proportion of moisture. Other seeds are carried indigested in the stomach of birds, and supplied with food at the moment of their deposition. The light seeds of the mosses and lichens probably float in every part of the atmosphere, and abound on the surface of the sea.

seed cake, one of the most nutritive substances on which they can be fed.*

* For the following observations on the selection of different kinds of common food by sheep and cattle, I am obliged to Mr. George Sinclair.

" *Lolium perenne*, rye-grass. Sheep eat this grass when it is in the early stage of its growth, in preference to most others; but after the seed approaches towards perfection, they leave it for almost any other kind. A field in the park at Woburn was laid down in two equal parts; one part with rye-grass and white clover, and the other part with cock's-foot and red clover: from the spring till midsummer the sheep kept almost constantly on the rye-grass; but after that time they left it and adhered with equal constancy to the cock's-foot during the remainder of the season.

" *Dactylis glomerata*, cock's-foot. Oxen, horses, and sheep eat this grass readily. The oxen continue to eat the straws and flowers, from the time of flowering till the time of perfecting the seed: this was exemplified in a striking manner in the field before alluded to. The oxen generally kept to the cock's-foot and red clover, and the sheep to the rye-grass and white clover. In the experiments published in the Amœnitates Academicæ, by the pupils of Linnæus, it is asserted that this grass is rejected by oxen: the above fact, however, is in contradiction of it.

" *Alopecurus pratensis*, meadow fox-tail. Sheep and horses seem to have a greater relish for this grass than oxen. It delights in a soil of intermediate quality as to moisture or dryness, and is very productive. In the water-meadow at Priestley, it constitutes a considerable part of the produce of that excellent meadow. It there keeps invariably possession of the top of the ridges, extending generally about six feet from each side of the water-course; the space below that to where the ridge ends is stocked with cock's-foot, the rough-stalked meadow grass, *Festuca pratensis*, *Festuca duriuscula*, *Agrostis stolonifera*, *Agrostis palustris*, and sweet-scented vernal grass, with a small admixture of some other kinds.

" *Phleum pratense*, meadow cat's-tail. This grass is eaten without reserve by oxen, sheep, and horses. Dr. Pulteney says that it is disliked by sheep; but in pastures where it abounds, it does not appear to be rejected by these animals, but eaten in common with such others as are growing with it. Hares are remarkably fond of it. The *Phleum nodosum*, *Phleum alpinum*, *Poa fertilis*, and *Poa compressa*, were left untouched, although they were closely adjoining to it. It seems to attain the greatest perfection in a rich deep loam.

" *Agrostis stolonifera*, fiorin. In the experiments detailed in the

When food artificially composed is to be given to cattle, it should be brought as nearly as possible to the

Amœnitates Academicæ, it is said that horses, sheep, and oxen eat this grass readily. On the Duke of Bedford's farm at Maulden, fiorin hay was placed in the racks before horses in small distinct quantities, alternately with common hay; but no decided preference for either was manifested by the horses in this trial. But that cows and horses prefer it to hay, when in a green state, seems fully proved by Dr. Richardson, in his several publications on fiorin; and of its productive powers in England (which has been doubted by some) there are satisfactory proofs. Lady Hardwicke has given an account of a trial of this grass; wherein twenty-three milch cows and one young horse, besides a number of pigs were kept a fortnight on the produce of one acre.

" *Poa trivialis*, rough-stalked meadow. Oxen, horses, and sheep eat this grass with avidity. Hares also eat it; but they give a decided preference to the smooth-stalked meadow grass, to which it is, in many respects, nearly allied.

" *Poa pratensis*, smooth-stalked meadow grass. Oxen and horses are observed to eat this grass in common with others; but sheep rather prefer the hard fescue, and sheep's fescue, which affect a similar soil. This species exhausts the soil in a greater degree than almost any other species of grass; the roots being numerous, and powerfully creeping, become in two or three years completely matted together; the produce diminishes as this takes place. It grows common in some meadows, dry banks, and even on walls.

" *Cynosurus cristatus*, crested dog's-tail grass. The South Down sheep and deer appear to be remarkably fond of this grass: in some parts of Woburn Park this grass forms the principal part of the herbage on which these animals chiefly browse; while another part of the park, that contains the *Agrostis capillaris*, *Agrostis pumilis*, *Festuca ovina*, *Festuca duriuscula*, and *Festuca cambrica*, is seldom touched by them: and the Welsh breed of sheep almost constantly browse upon these, but neglect the *Cynosurus cristatus*, *Lolium perenne*, and *Poa trivialis*.

" *Agrostis vulgaris* (*capillaris*, Linn.), fine bent; common bent. This is a very common grass on all poor dry sandy soils. It is not palatable to cattle, as they never eat it readily, if any other kinds be within their reach. The Welsh sheep, however, prefer it, as I before observed; and it is singular that those sheep being bred in the park, when some of the best grasses are equally within their reach, should still prefer those grasses which naturally grow on the Welsh mountains: it seems to argue that such a preference is the effect of some other cause than that of habit.

" *Festuca ovina*, sheep's fescue. All kinds of cattle relish this grass;

state of natural food. Thus, when sugar is given to them, some dry fibrous matter should be mixed with it.

but it appears from the trial that has been made with it on clayey soils, that it continues but a short time in possession of such, being soon overpowered by the more luxuriant kinds. On dry shallow soils that are incapable of producing the larger sorts, this should form the principal crop, or rather the whole; for it is seldom or ever, in its natural state, found intimately mixed with others, but by itself.

" *Festuca duriuscula*, hard fescue grass. This is certainly one of the best of the dwarf sorts of grasses. It is grateful to all kinds of cattle; hares are very fond of it; they cropped it close to the roots, and neglected the *Festuca ovina* and *Festuca rubra*, which were contiguous to it. It is present in most good meadows and pastures.

" *Festuca pratensis*, meadow fescue. This grass is seldom absent from rich meadows and pastures; it is observed to be highly grateful to oxen, sheep, and horses, particularly the former. It appears to grow luxuriantly when combined with the hard fescue and *Poa trivialis.*

" *Avena elatior*, tall oat-grass. This is a very productive grass, frequent in meadows and pastures, but is disliked by cattle, particularly by horses; this perfectly agrees with the small portion of nutritive matter which it affords. It seems to thrive best on a strong tenacious clay.

" *Avena flavescens*, yellow oat-grass. This grass seems partial to dry soils and meadows, and appears to be eaten by sheep and oxen equally with the meadow barley, crested dog's-tail, and sweet-scented vernal grasses, which naturally grow in company with it. It nearly doubles the quantity of its produce by the application of calcareous manure.

" *Holcus lanatus*, meadow soft grass. This is a very common grass, and grows on all soils, from the richest to the poorest. It affords an abundance of seed, which is light, and easily dispersed by the wind. It appears to be generally disliked by all sorts of cattle. The produce is not so great as a view of it in fields would indicate; but being left almost entirely untouched by cattle, it appears as the most productive part of the herbage. The hay which is made of it, from the number of downy hairs which cover the surface of the leaves, is soft and spongy, and disliked by cattle in general.

" *Anthoxanthum odoratum*, sweet-scented vernal grass. Horses, oxen, and sheep eat this grass; though in pastures where it is combined with the meadow fox-tail, and white clover, cock's-foot, rough-stalked meadow, it is left untouched; from which it would seem unpalatable to cattle. Mr. Grant of Leighton laid down one-half of a field of considerable extent with this grass combined with white clover. The other half of the

such as chopped straw, or dry withered grass, in order that the functions of the stomach and bowels may be performed in a natural manner. The principle is the same as that of the practice alluded to in the Third Lecture, of giving chopped straw with barley.

In washing sheep, the use of water containing carbonate of lime, should be avoided; for this substance decomposes the yolk of the wool, which is an animal soap, the natural defence of the wool: and wool, often washed in calcareous water, becomes rough and more brittle. The finest wool, such as that of the Spanish and Saxon sheep, is most abundant in yolk. M. Vauquelin has analyzed several different species of yolk, and has found the principal part of all of them a soap, with a basis of potassa (*i. e.* a compound of oily matter and potassa), with a little oily matter in excess. He has found in them, likewise, a notable quantity of acetate of potassa, and minute quantities of carbonate of potassa, and muriate of potassa, and a peculiar odorous animal matter.

M. Vauquelin states, that he found some specimens of wool lose as much as 45 per cent. in being deprived of their yolk; and the smallest loss in his experiments was 35 per cent.

The yolk is most useful to the wool on the back of the sheep in cold and wet seasons; probably the application of a little soap of potassa, with excess of grease

field with fox-tail and red clover. The sheep would not touch the sweet-scented vernal, but kept constantly upon the fox-tail. The writer of this saw the field when the grasses were in the highest state of perfection; and hardly anything could be more satisfactory. Equal quantities of the seeds of white clover were sown with each of the grasses; but from the dwarf nature of the sweet-scented vernal grass, the clover mixed with it had attained to greater luxuriance than that mixed with the meadow fox-tail."

to the sheep brought from warmer climates in our winter,—that is, increasing their yolk artificially, might be useful in cases where the fineness of the wool is of great importance. A mixture of this kind is more conformable to nature, than that ingeniously adopted by Mr. Bakewell; but at the time his labours commenced, the chemical nature of the yolk was unknown.

I have now exhausted all the subjects of discussion, which my experience or information have been able to supply on the connection of chemistry with agriculture.

I venture to hope that some of the views brought forward, may contribute to the improvement of the most important and useful of the arts.

I trust that the inquiry will be pursued by others; and that, in proportion as chemical philosophy advances towards perfection, it will afford new aids to agriculture.

There are sufficient motives, connected both with pleasure and profit, to encourage ingenious men to pursue this new path of investigation. Science cannot long be despised by any persons as the mere speculation of theorists; but must soon be considered by all ranks of men in its true point of view, as the refinement of common sense, guided by experience, gradually substituting sound and rational principles for vague popular prejudices.

The soil offers inexhaustible resources, which, when properly appreciated and employed, must increase our wealth, our population, and our physical strength.

We possess advantages in the use of machinery, and the division of labour, belonging to no other nation. And the same energy of character, the same extent of resources, which have always distinguished the people

of the British Islands, and made them excel in arms, commerce, letters, and philosophy, apply with the happiest effect to the improvement of the cultivation of the earth. Nothing is impossible to labour, aided by ingenuity. The true objects of the agriculturist, are likewise those of the patriot. Men value most what they have gained with effort; a just confidence in their own powers, results from success; they love their country better, because they have seen it improved by their own talents and industry; and they identify with their interests, the existence of those institutions which have afforded them security, independence, and the multiplied enjoyments of civilized life.

APPENDIX I.

An Account of the Results of Experiments on the Produce and Nutritive Qualities of Different Grasses, and other Plants, used as the Food of Animals, instituted by John Duke of Bedford.

INTRODUCTION BY SIR. H. DAVY.

Of the 215 proper grasses which are capable of being cultivated in this climate, two only have been employed to any extent for making artificial pastures, — rye-grass and cock's-foot grass; and their application for this purpose seems to have been rather the result of accident than of any proofs of their superiority over other grasses.

A knowledge of the comparative merits and value of all the different species and varieties of grasses cannot fail to be of the highest importance in practical agriculture. The hope of obtaining this knowledge was the motive that induced the Duke of Bedford to institute this series of experiments.

Spots of ground, each containing four square feet, in the garden at Woburn Abbey, were inclosed by boards in such a manner that there was no lateral communication between the earth included by the boards and that of the garden. The soil was removed in these inclosures, and new soils supplied; or a mixture of soils was made in them, to furnish as far as possible to the different grasses those soils which seem most favourable to their growth; a few varieties being adopted for the purpose of ascertaining the effect of different soils on the same plant.

The grasses were either planted or sown, and their produce cut and collected and dried, at the proper

seasons, in summer and autumn, by Mr. Sinclair, his Grace's gardener. For the purpose of determining, as far as possible, the nutritive powers of the different species, equal weights of the dry grasses or vegetable substances were acted upon by hot water till all their soluble parts were dissolved; the solution was then evaporated to dryness by a gentle heat in a proper stove, and the matter obtained carefully weighed. This part of the process was likewise conducted with much address and intelligence by Mr. Sinclair, by whom all the following details and calculations are furnished.

The dry extracts, supposed to contain the nutritive matter of the grasses, were sent to me for chemical examination. The composition of some of them is stated in the table, page 298 of the preceding volume; I shall offer a few chemical observations on others at the end of this Appendix. It will be found from the general conclusions, that the mode of determining the nutritive power of the grasses, by the quantity of matter they contain soluble in water, is sufficiently accurate for all the purposes of agricultural investigation.

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Details of Experiments on Grasses. *By* GEORGE SINCLAIR *Gardener to his Grace the* DUKE *of* BEDFORD, *and Corresponding Member of the Horticultural Society of Edinburgh.*

I. *Anthoxanthum odoratum.* Engl. Bot. 647. — Curt. Lond.

Sweet-scented vernal-grass. Nat. of Britain.

At the time of flowering, the produce from the space of an acre equal to ·000091827364 of a brown sandy loam with manure, is —

		oz.	or lbs. per acre.		
Grass, 11 oz. 8 dr.* The produce per acre		125235	0=7827	3	0
80 dr. of grass weigh when dry -	21½ dr.	33656	0=2103	8	0
The produce of the space, ditto -	49.1$\frac{8}{10}$				
The weight lost by the produce of one acre in drying - -			5723	10	0
64 dr. of grass afford of nutritive matter 1 dr.		1956	12= 122	4	12
The produce of the space, ditto -	2·3$\frac{5}{10}$				

At the time the seed is ripe, the produce is—

Grass, 9 oz. The produce per acre - -		98010	0=6125	10	0
80 dr. of grass weigh when dry -	24 dr.	29403	0=1837	11	0
The produce of the space, ditto -	43$\frac{1}{16}$				
The weight lost by the produce of one acre in drying -			4287	15	0
64 dr. of grass afford of nutritive matter 3·1 dr.		4977	10= 311	1	1
The produce of the space, ditto -	7·1¼				
The weight of nutritive matter which is lost by taking the crop at the time the grass is in flower, exceeding half of its value			188	12	4

The proportional value which the grass at the time of flowering bears to that at the time the seed is ripe, is as 4 to 13.

The latter-math produce is—

Grass, 10 oz. The produce per acre -	108900	0=6806	4	0
64 dr. of grass afford of nutritive matter 2.1 dr.	3828	8= 239	4	8

The proportional value which the grass of the latter-

* The weight is avoirdupois; lbs. pound, oz. ounces, dr. drachms. The weights not named are quarters of drachms, and fractions of quarters of drachms; thus 7·1¼ means 7 drachms, 1 quarter of a drachm, and ¼ of a quarter.

math bears to that at the time the seed is ripe, is nearly as 9 to 13.

The smallness of the produce of this grass renders it improper for the purpose of hay; but its early growth, and the superior quantity of nutritive matter which the latter-math affords, compared with the quantity afforded by the grass at the time of flowering, causes it to rank high as a pasture grass, on such soils as are well fitted for its growth; such are peat-bogs, and lands that are deep and moist.

II. *Holcus odoratus.* Host. G. A. Growing in woods. Sweet-scented soft grass. Nat. of Germany. Flo. Ger.—H. borealis. Growing in moist meadows.

At the time of flowering, the produce from a rich sandy loam is —

		oz.		or lbs. per acre.		
Grass, 14 oz. The produce per acre	-	152460	0=	9528	12	0
80 dr. of grass weigh when dry - 20·2 dr. / The produce of the space, ditto - 57.1$\frac{3}{5}$		39067	14=	2441	11	14
The weight lost by the produce of one acre in drying	-			7087	0	2
64 dr. of grass afford of nutritive matter 4.1 dr. / The produce of the space, ditto - 14.3$\frac{1}{2}$		10124	13=	610	15	5

At the time the seed is ripe the produce is —

Grass, 40 oz. The produce per acre	-	435600	0=	27225	0	0
64 dr. of grass weigh when dry - 28 dr. / The produce of the space, ditto - 224		152460	0=	9528	12	0
The weight lost by the produce of one acre in drying	-			17696	4	0
64 dr. of grass afford of nutritive matter 5·1 dr. / The produce of the space, ditto - 52·2		35732	13=	2233	4	13
The weight of nutritive matter which is lost by taking the crop at the time the grass is in flower, being more than half of its value. - - - -				1600	8	10

The proportional value which the grass at the time of flowering bears to that at the time the seed is ripe, is as 17 to 21.

The produce of latter-math is —

Grass, 25, oz. The produce per acre	-	272250	0=	17015	10	0
64 dr. of grass afford of nutritive matter 4·1 dr.		18079	1=	1129	15	1

The grass of the latter-math crop, and of the crop at the time of flowering, taking the whole quantity, and their relative proportions of nutritive matter, are in value nearly as 6 to 10; the value of the grass at the

time the seed is ripe exceeds that of the latter-math in proportion as 21 to 17.

Though this is one of the earliest of the flowering grasses, it is tender, and the produce in the spring is inconsiderable. If, however, the quantity of nutritive matter which it affords be compared with that of any of those species which flower nearly at the same time, it will be found greatly superior. It sends forth but a small number of flower stalks, which are of a slender structure compared to the size of the leaves. This will account in a great measure for the equal quantities of nutritive matter afforded by the grass at the time of flowering, and the latter-math.

III. *Cynosurus cæruleus.* Engl. Bot. 1613. Host. G. A. ii. t. 98.

Blue moor-grass. Nat. of Britain. Sesleria cærulea.

At the time the seed is ripe, the produce from a light sandy soil is—

	oz.	or lbs. per acre.
Grass, 10 oz. The produce per acre -	1089000 0	=6806 4 0
64 dr. of grass afford of nutritive matter 3.3 dr.	6380 13	= 398 12 13

The produce of this grass is greater than its appearance would denote; the leaves seldom attain to more than four or five inches in length, and the flower-stalks seldom rise to more. Its growth is not rapid after being cropped, nor does it seem to withstand the effects of frost, which, if it happen to be severe and early in the spring, checks it so much as to prevent it from flowering for that season; otherwise the quantity of nutritive matter which the grass affords (for the straws are very inconsiderable) would rank it as a valuable grass for permanent pasture.

IV. *Alopecurus pratensis.* Curt. Lond. Alo. myosuroides.

Meadow fox-tail grass. Nat. of Brit. Engl. Bot. 848.

At the time of flowering, the produce from a clayey loam is—

		oz.		or lbs. per acre.		
Grass, 30 oz. The produce per acre	-	326700	0=	20418	12	0
80 dr. of grass weigh when dry -	24 dr.	98010	0=	6125	10	0
The produce of the space, ditto -	336					
The weight lost by the produce of one acre in drying		-		14293	2	0
64 dr. of grass afford of nutritive matter	1·2 dr.	7657	0=	478	9	0
The produce of the space, ditto -	11·1					

The produce from a sandy loam is—

Grass, 12 oz. 8 dr. The produce per acre	-	136125	0=	8507	13	0
80 dr. of grass weigh when dry -	24 dr.	40837	9=	2552	5	8
The produce of the space, ditto -	60					
64 dr. of grass afford of nutritive matter	1	2126	15=	132	14	15
The produce of the space, ditto -	3·0½					

At the time the seed is ripe, the produce from the clayey loam is—

Grass, 19 oz. The produce per acre	-	206910	0=	12931	14	0
80 dr. of grass weigh when dry -	36 dr.	93109	8=	5819	5	2
The produce of the space, ditto -	136·3⅕					
The weight lost by the produce of one acre in drying		-		7111	8	14
64 dr. of grass afford of nutritive matter	2·1 dr.	7376	4=	461	0	4
The produce of the space, ditto -	9·975					
The weight of nutritive matter which is lost by leaving the crop till the seed be ripe, being one twenty-fifth part of its value		-		17	8	11

The proportional value which the grass at the time of flowering bears to that at the time the seed is ripe, is as 6 to 9.

The latter-math produce, from the clayey loam, is—

Grass, 12 oz. The produce per acre	-	130680	0=	8167	8	0
64 dr. of grass afford of nutritive matter	2 dr.	4083	12=	255	3	12
The produce of the space, ditto -	6					

The proportional value which the whole of the latter-math crop bears to that at the time the seed is ripe, is as 5 to 9; and to that at the time of flowering, proportionably as 13 to 24.

The above statement clearly shows that there is nearly three fourths of produce greater from a clayey loam than from a sandy soil, and the grass from the latter is comparatively of less value, in proportion as 4 to 6. The straws produced by the sandy soil are deficient in number, and in every respect less than those from the clayey loam; which will account for the unequal quantities of nutritive matter afforded by them; but the proportional value in which the grass of the latter-math

exceeds that of the crop at the time of flowering, is as 4 to 3: a difference which appears extraordinary, when the quantity of flower-stalks which are in the grass at the time of flowering is considered. In the *Anthoxanthum odoratum* the proportional difference between the grass of these crops is still greater, nearly as 4 to 9: in the *Poa pratensis* they are equal; but in all the latter flowering grasses experimented upon, the flowering straws of which resemble those of the *Alopecurus pratensis*, or *Anthoxanthum odoratum*, the greater proportional value is always, on the contrary, found in the grass of the flowering crop. Whatever the cause may be, it is evident that the loss sustained by taking the crops of these grasses at the time of flowering is considerable.

V. *Alopecurus alpinus.* Engl. Bot. 1126.
Alpine fox-tail grass. Nat. of Scotland.

At the time of flowering, the produce from a sandy loam, with a small portion of manure, is—

		oz.	or lbs. per acre.		
Grass, 8 oz. The produce per acre -		87120	0= 5445	5	0
60 dr. of grass weigh when dry -	16 dr.	23232	0= 1452	0	0
The produce of the space, ditto -	$34\frac{2}{16}$				
The weight lost by the produce of one acre in drying -			3993	5	0
64 dr. of grass afford of nutritive matter	1 dr.	1361	4= 85	1	4
The produce of the space, ditto -	2				

VI. *Poa alpina.* Engl. Bot. 1003. Flor. Dan. 107.
Alpine meadow-grass. Nat. of Scotland.

At the time of flowering, the produce from a light sandy loam is—

Grass, 8 oz. The produce per acre -		87120	0= 5445	0	0
64 dr. of grass afford of nutritive matter	1·2 dr.	2041	14= 127	9	14

VII. *Avena pubescens.* Engl. Bot. 1640. Host. G. A. ii. t. 50.
Downy oat-grass. Nat. of Britain.

At the time of flowering, the produce from a rich sandy soil is—

		oz.		or lbs. per acre.		
Grass, 23 oz. The produce per acre -		250470	0=	15654	6	0
80 dr. of grass weigh when dry -	30 dr.	93926	0=	5870	6	4
The produce of the space, ditto -	138					
The weight lost by the produce of one acre in drying -				9783	15	12
64 dr. of grass afford of nutritive matter	1·2 dr.	5870	0=	366	14	6
The produce of the space, ditto -	$8{\cdot}2\frac{2}{16}$					

At the time the seed is ripe, the produce is—

Grass, 10 oz. The produce per acre -		108900	0=	6806	4	0
80 dr. of grass weigh when dry -	16 dr.	21780	0=	1361	4	0
The produce of the space, ditto -	32					
The weight lost by the produce of one acre in drying -				5545	0	0
64 dr. of grass afford of nutritive matter	2 dr.	3403	2=	212	11	0
The produce of the space, ditto -	5					
The weight of nutritive matter which is lost by leaving the crop till the seed be ripe, being more than half of its value - - - - - -				154	6	3

The proportional value which the grass at the time of flowering bears to that at the time the seed is ripe, is as 6 to 8.

The produce of latter-math is—

Grass, 10 oz. The produce per acre -	108900	0=	6806	4	0
64 dr. of grass afford of nutritive matter 2 dr.	3403	2=	212	11	0

The proportional value which the grass at the time of flowering bears to that of the latter-math, is as 6 to 8. The grass of the seed-crop, and that of the latter-math, are of equal value.

The downy hairs which cover the surface of the leaves of this grass, when growing on poor light soils, almost entirely disappear when it is cultivated on a richer soil. It possesses several good qualities which recommend it to particular notice; it is hardy, early, and more productive than many others which affect similar soils and situations. Its growth after being cropped is tolerably rapid, although it does not attain to a great length if left growing: like the *Poa pratensis*, it sends forth flower-stalks but once in a season, and it appears well calculated for permanent pasture on rich light soils.

VIII. *Poa pratensis*. Curt. Lond. Engl. Bot. 1073.

Smooth-stalked meadow grass. Nat. of Britain.

At the time of flowering, the produce from a mixture of bog-earth and clay is—

		oz.	or lbs. per acre.		
Grass, 15 oz. The produce per acre -		163350	0=10209	6	0
80 dr. of grass weigh when dry -	22·2 dr.	45942	3= 2871	6	3
The produce of the space, ditto -	67·2				
The weight lost by the produce of one acre in drying -			7337	15	13
34 dr. of grass afford of nutritive matter	1·3 dr.	4466	9= 279	2	9
The produce of the space, ditto -	$6{\cdot}2\frac{1}{16}$				

At the time the seed is ripe, the produce is—

Grass, 12·8 oz. The produce per acre -		136125	0= 8507	13	0
80 dr. of grass weigh when dry -	32 dr.	5445	0= 3403	2	0
The produce of the space, ditto -	80				
The weight lost by the produce of one acre in drying -			5104	11	0
64 dr. of grass afford of nutritive matter	1·2 dr.	3190	6= 199	6	0
The produce of the space, ditto -	$4{\cdot}2\frac{3}{16}$				
The weight of nutritive matter which is lost by leaving the crop till the seed be ripe, being nearly one-fourth of its value -			79	12	9

The produce of latter-math is—

Grass, 6 oz. The produce per acre -		65340	0= 4083	12	0
64 dr. of grass afford of nutritive matter	1·3 dr.	1786	10= 111	10	0

The proportional value in which the grass of the latter-math exceeds that of the flowering crop, is as 6 to 7. The grass of the seed-crop and that of the latter-math are of equal value.

This grass is, therefore, of least value at the time the seed is ripe; a loss of more than one-fourth of the value of the whole crop is sustained if it is not cut till that period: the straws are then dry, and the root-leaves in a sickly decaying state; those of the latter-math, on the contrary, are luxuriant and healthy. This species sends forth flower-stalks but once in a season; and these being the most valuable part of the plant for the purpose of hay, it will, from this circumstance, and the superior value of the grass of the latter-math compared to that of the seed-crop, appear well adapted for permanent pasture.

IX. *Poa cærulea.*—Var. *Poa pratensis.* Engl. Bot. 1004, Poa subcærulea.

Short bluish meadow grass. Nat. of Britain. H. Kew. 1—155. Poa humilis.

At the time of flowering, the produce from a soil of the like nature as the preceding is—

		oz.	or lbs. per acre.		
Grass, 11 oz. The produce per acre -		119790	0=7486	14	0
64 dr. of grass afford of nutritive matter	2 dr.	3743	7= 233	15	0
The produce of the space, ditto -	5·2				
80 dr. of grass weigh when dry -	24	35937	0=2246	1	0
The produce of the space, ditto -	52·3$\frac{3}{16}$				
The weight lost by the produce of one acre in drying -			5240	13	0

If the produce of this variety be compared with that of the preceding one, it will be found less; nor does it seem to possess any superior excellence. The superior nutritive power does not make up for the deficiency of produce by 80 lbs. of nutritive matter per acre.

X. *Festuca hordiformis.* Poa hordiformis. H. Cant.

Barley-like fescue grass. Nat. of Hungary.

At the time of flowering, the produce from a sandy soil, with manure, is—

Grass, 20 oz. The produce per acre -		217800	0=13612	8	0
80 dr. of grass weigh when dry -	24 dr.	65340	0= 4083	12	0
The produce of the space, ditto -	96				
The weight lost by the produce of one acre in drying -			9528	12	0
64 dr. of grass afford of nutritive matter	2·1 dr.	7657	0= 478	9	0
The produce of the space, ditto -	11·1				

This is rather an early grass, though later than any of the preceding species; its foliage is very fine, resembling the *F. duriuscula*, to which it seems nearly allied, differing only in the length of the awns, and the glaucous colour of the whole plant. The considerable produce it affords, and the nutritive powers it appears to possess, joined to its early growth, are qualities which strongly recommended it to further trial.

XI. *Poa trivialis.* Curt. Lond. Engl. Bot. 1072. Host. G. A. ii. t. 62.

Roughish meadow grass. Nat of Britain.

At the time of flowering, the produce from a light brown loam, with manure, is—

		oz.	or lbs. per acre.		
Grass, 11 oz. The produce per acre -		119790	0=7486	14	0
80 dr. of grass weigh when dry -	24 dr.	35937	0=2246	1	0
The produce of the space, ditto -	54$\frac{3}{16}$				
The weight lost by the produce of one acre in drying -			5240	13	0
64 dr. of grass afford of nutritive matter	2 dr.	3743	7= 233	15	7
The produce of the space, ditto -	5·2				

At the time the seed is ripe, the produce is—

		oz.		or lbs. per acre.		
Grass, 11·8 oz. The produce per acre -		125235	0	=7827	3	0
80 dr. of grass weigh when dry - 36 dr. The produce of the space, ditto -	$82{\cdot}3\frac{3}{16}$	56355	12	=3522	3	12
The weight lost by the produce of one acre in drying -				4304	15	4
64 dr. of grass afford of nutritive matter 2·3 dr. The produce of the space, ditto -	$7{\cdot}3\frac{3}{5}$	5381	3	= 336	5	3
The weight of nutritive matter which is lost by taking the crop at the time of flowering, exceeding one-fourth of its value				102	5	12

The proportional value in which the grass of the seed-crop exceeds that at the time of flowering, is as 8 to 11.

The produce of the latter-math is—

Grass, 7 oz. The produce per acre -	76230	0	=4764	6	0
64 dr. of grass afford of nutritive matter 3 dr.	3573	4	= 223	5	4

The proportional value by which the grass of the latter-math exceeds that of the flowering crop, is as 8 to 12, and that of the seed-crop as 11 to 12.

Here, then, is a satisfactory proof of the superior value of the crop at the time the seed is ripe, and of the consequent loss sustained by taking it when in flower; the produce of each crop being nearly equal. The deficiency of hay in the flowering crop, in proportion to that of the seed-crop, is very striking. Its superior produce, the highly nutritive powers which the grass seems to possess, and the season in which it arrives at perfection, are merits which distinguish it as one of the most valuable of those grasses which affect moist rich soils on sheltered situations; but on dry exposed situations it is altogether inconsiderable; it yearly diminishes, and ultimately dies off, not unfrequently in the space of four or five years.

XII. *Festuca glauca.* Curtis.

Glaucous fescue-grass. Nat. of Britain.

At the time the seed is ripe the produce from a brown loam is—

Grass, 14 oz. The produce per acre -		152460	0	=9528	12	0
80 dr. of grass weigh when dry - 32 dr. The produce of the space, ditto -	$89{\cdot}2\frac{1\cdot2}{16\cdot32}$	60984	0	=3811	8	0
The weight lost by the produce of one acre in drying -				5717	4	0
64 dr. of grass afford of nutritive matter 1·2 dr. The produce of the space, ditto -	5·1	2573	4	= 233	5	4

At the time of flowering, the produce is—

		oz.	or lbs. per acre		
Grass, 14 oz. The produce per acre -		152460	0=9528	12	0
80 dr. of grass weigh when dry -	32 dr.	60984	0=4811	8	0
The produce of the space, ditto -	89·2⅖				
The weight lost by the produce of one acre in drying -			5717	4	0
64 dr. of grass afford of nutritive matter	3 dr.	7146	9= 446	10	9
The produce of the space, ditto -	10·2				
The weight of nutritive matter which is lost by leaving the crop till the seed be ripe, being half of the value of the crop -			223	5	5

The proportional value by which the grass at the time of flowering exceeds that at the time the seed is ripe, is as 6 to 12.

The proportional difference in the value of the flowering and seed crops of this grass is directly the reverse of that of the preceding species, and affords another strong proof of the value of the straws in grass which is intended for hay. The straws at the time of flowering are of a very succulent nature; but from that period till the seed be perfected, they gradually become dry and wiry. Nor do the root-leaves sensibly increase in number or in size, but a total suspension of increase appears in every part of the plant, the roots and seed-vessels excepted. The straws of the *Poa trivialis* are, on the contrary, at the time of flowering, weak and tender; but as they advance towards the period of ripening the seed, they become firm and succulent; after that period, however, they rapidly dry up, and appear little better than a mere dead substance.

XIII. *Festuca glabra.* Wither. B. ii. p. 154.

Smooth fescue-grass. Nat. of Scotland.

At the time of flowering, the produce from a clayey loam with manure is—

Grass, 21 oz. The produce per acre -		228690	0=14293	0	0
80 dr. of grass weigh when dry -	32 dr.	91476	0= 5717	4	0
The produce of the space, ditto -	$134{\cdot}1\frac{22}{165}$				
The weight lost by the produce of one acre in drying -			8576	14	0
64 dr. of grass afford of nutritive matter	2 dr.	7146	0= 446	10	0
The produce of the space, ditto -	10·2				

At the time the seed is ripe, the produce is—

		oz.	or lbs. per acre.		
Grass, 14 oz. The produce per acre -		152460 0=	9528	12	0
80 dr. of grass weigh when dry - 32 dr.	}	60984 0=	3811	8	0
The produce of the space, ditto - 89·2⅗					
The weight lost by the produce of one acre in drying -			5717	4	0
64 dr. of grass afford of nutritive matter 1·1 dr.	}	2977 11=	186	1	11
The produce of the space, ditto - 4·1¾					
The weight of nutritive matter which is lost by leaving the crop till the seed be ripe, exceeding half of its value -			260	9	0

The proportional value which the grass at the time the seed is ripe bears to that of the crop at the time of flowering, is as 5 to 8.

The produce of latter-math is—

Grass, 9 oz. The produce per acre -		98010 0=	6125	10	0
64 dr. of grass afford of nutritive matter 2 dr.	}	765 11=	47	13	0
The produce of the space, ditto - 1·0½					

The proportional value which the grass of the latter-math bears to that of the crop at the time of flowering is as 2 to 8, and to that of the crop at the time the seed is ripe is as 2 to 5.

The general appearance of this grass is very similar to that of the *Festuca duriuscula:* it is, however, specifically different, and inferior in many respects, which will be manifest on comparing their several produce with each other; but if it be compared with some others, now under general cultivation, the result is much in its favour, the soil which it affects being duly attended to. The *Anthoxanthum odoratum* being taken as an example, it appears that

Festuca glabra affords of nutritive matter—

		lbs. per acre.
From the crop at the time of flowering	446 }	- 632
At the time the seed is ripe, ditto -	186	
Anthoxanthum odoratum,		
At the time of flowering, ditto -	122 }	- 433
At the time the seed is ripe, ditto -	311	
The weight of nutritive matter which is afforded by the produce of one acre of the *Festuca glabra,* exceeding that of the *Anthoxanthum odoratum* in proportion nearly as 6 to 9 -		199

XIV. *Festuca rubra.* Wither. B. ii. p. 153.
Purple fescue-grass. Nat. of Britain.

At the time of flowering, the produce from a light sandy soil is—

		oz.		or lbs. per acre.		
Grass, 15 oz. The produce per acre -		163350	0 =	10209	6	0
80 dr. of grass weigh when dry - The produce of the space, ditto -	34 dr. 102	56923	12 =	3557	11	0
The weight lost by the produce of one acre in drying -				6651	11	0
64 dr. of grass afford of nutritive matter The produce of the space, ditto -	1·2 dr. $22\frac{2}{16}$	3828	8 =	239	4	8

At the time the seed is ripe, the produce is—

Grass, 16 oz. The produce per acre -		174240	0 =	10890	0	0
80 dr. of grass weigh when dry - The produce of the space, ditto -	36 dr. $115\frac{3}{16}$	78408	0 =	4900	8	0
The weight lost by the produce of one acre in drying -				5989	8	0
64 dr. of grass afford of nutritive matter The produce of the space, ditto -	2 dr. 8	5445	0 =	340	5	0
The weight of nutritive matter which is lost by taking the crop when the grass is in flower, being nearly one-third part of its value - - - - -				101	0	8

The proportional value which the grass at the time of flowering bears to that at the time the seed is ripe, is as 6 to 8.

This species is smaller in every respect, than the preceding. The leaves are seldom more than from three to four inches in length; it affects a soil similar to that favourable to the growth of the *Festuca ovina*, for which it would be a profitable substitute, as will clearly appear on a comparison of their produce with each other.

The produce of latter-math is—

Grass, 5 oz. The produce per acre -	54450	0 =	3403	2	0
64 dr. of grass afford of nutritive matter 1·2 dr.	1276	2 =	79	12	0

The proportional value which the grass of the latter-math bears to that at the time the seed is ripe, is as 6 to 8, and is of equal value with the grass at the time of flowering.

XV. *Festuca ovina.* Engl. Bot. 585. Wither. B. ii. p. 152.

Sheep's fescue-grass. Nat. of Britain.

At the time the seed is ripe, the produce is—

Grass, 8 oz. The produce per acre - -		87120	0 =	5445	0	0
64 dr. of grass afford of nutritive matter The produce of the space, ditto -	1·2 dr. 3	2031	14 =	127	9	0

The produce of latter-math is—

Grass, 5 oz. The produce per acre -	54450	0 =	3403	2	0
64 dr. of grass afford of nutritive matter 1·1 dr.	1063	7 =	66	7	7

The dry weight of this species was not ascertained, because the smallness of the produce renders it entirely unfit for hay. If the nutritive powers of this species be compared with those of the preceding, the inferiority will appear thus:

Festuca ovina (as above) affords of nutritive matter			1·2	- - 2·3
Ditto	ditto	ditto	1·1	
Festuca rubra	ditto	ditto	2	- - 3·2
Ditto	ditto	ditto	1·2	

The comparative degree of nourishment which the grass of the *Festuca rubra* affords, exceeds therefore that afforded by the *F. ovina* in proportion as 11 to 14.

From the trial that is here detailed, it does not seem to possess the nutritive powers generally ascribed to it; it has the advantage of a fine foliage, and may, therefore, very probably, be better adapted to the masticating organs of sheep, than the larger grasses, whose nutritive powers are shown to be greater: hence, on situations where it naturally grows, and as pasture for sheep, it may be inferior to few others. It possesses natural characters very distinct from *F. rubra.*

XVI. *Briza media.* Engl. Bot. 340. Host. G. A. ii. t. 29.

Common quaking-grass. Nat. of Britain.

At the time of flowering, the produce from a rich brown loam, is—

		oz.		or lbs. per acre.		
Grass, 14 oz. The produce per acre	-	152460	0 =	9528	12	0
80 dr. of grass weigh when dry -	26 dr.	49549	8 =	3096	13	8
The produce of the space, ditto -	$72 \cdot 3\frac{1}{16}$					
The weight lost by the produce of one acre in drying			-	6431	14	8
64 dr. of grass afford of nutritive matter	2·3 dr.	6551	0 =	409	7	0
The produce of the space, ditto -	$9 \cdot 2\frac{2}{16}$					

At the time the seed is ripe, the produce is—

Grass, 14 oz. The produce per acre	-	152460	0 =	9528	12	0
80 dr. of grass weigh when dry -	28 dr.	53362	0 =	3335	1	0
The produce of the space, ditto -	$78 \cdot 1\frac{3}{5}$					
The weight lost by the produce of one acre in drying			-	6183	11	0
64 dr. of grass afford of nutritive matter	3·1 dr.	7742	1 =	483	14	1
The produce of the space, ditto -	$11 \cdot 1\frac{1}{2}$					
The weight of nutritive matter which is lost by taking the crop at the time of flowering, being nearly one-fourth part of its value - - - - - - -			-	109	1	0

The proportional value which the grass at the time of flowering bears to that at the time the seed is ripe, is as 11 to 13.

The latter-math produce is—

	oz.		or lbs. per acre.		
Grass, 12 oz. The produce per acre -	130680	0 =	8167	8	0
64 dr. of grass afford of nutritive matter 2 dr.	483	12 =	255	3	12

The proportional value in which the grass at the time of flowering exceeds that of the latter-math, is as 8 to 11; and the latter-math stands to that at the time the seed is ripe, in proportion as 8 to 13.

The merits of this grass seem to demand notice; its nutritive powers are considerable and its produce large, when compared with others which affect a similar soil.

XVII. *Dactylis glomerata.* Engl. Bot. 335. Fl. Dan. 743.

Round-headed cock's-foot grass. Nat. of Britain. Wither. B. ii. p. 149.

At the time of flowering, the produce from a rich sandy loam is—

Grass, 41 oz. The produce per acre -		446490	0 =	27905	10	0
80 dr. of grass weigh when dry -	34 dr.	189758	4 =	11859	14	4
The produce of the space, ditto -	$278\frac{4}{5}$					
The weight lost by the produce of one acre in drying -				16045	11	12
64 dr. of grass afford of nutritive matter 2·2 dr.		17424	0 =	1089	0	0
The produce of the space, ditto -	$25{\cdot}2\frac{1}{2}$					

At the time the seed is ripe, the produce is—

Grass, 39 oz. The produce per acre -		424710	0 =	26544	6	0
80 dr. of grass weigh when dry -	40 dr.	21235	0 =	13272	3	0
The produce of the space, ditto -	312					
The weight lost by the produce of one acre in drying -				13272	3	0
64 dr. of grass afford of nutritive matter 3·2 dr.		23226	5 =	1451	10	0
The produce of the space, ditto -	$34{\cdot}0\frac{1}{2}$					
The weight of nutritive matter which is gained by leaving the crop till the seed be ripe, being more than one-third part of its value, is - - - - -				362	10	5

The proportional value which the grass at the time of flowering bears to that at the time the seed is ripe, is as 5 to 7, nearly.

The produce of latter-math is—

Grass, 17 oz. 8 dr. The produce per acre -	190575	0 =	11910	15	0
64 dr. of grass afford of nutritive matter 1·2 dr.	4466	0 =	281	10	9

The proportional value which the grass of the latter-math bears to that at the time of flowering is as 6 to 10; and to that at the time the seed is ripe, as 6 to 14. 64 dr. of the straws at the time of flowering afford of nutritive matter 1·2 dr. The leaves or latter-math, and the straws simply, are therefore of equal proportional value; a circumstance which will point out this grass to be more valuable for permanent pasture, than for hay. The above details prove, that a loss of nearly one-third of the value of the crop is sustained, if it is left till the period when the seed is ripe,—though the proportional value of the grass at that time is greater, *i. e.* as 7 to 5. The produce does not increase, if the grass is left growing after the period of flowering, but uniformly decreases; and the loss of latter-math, which (from the rapid growth of the foliage after the grass is cropped) is very considerable. These circumstances point out the necessity of keeping this grass closely cropped, either with the scythe or cattle, to reap the full benefit of its great merits.

XVIII. *Bromus tectorum*. Host. G. A. i. t. 15.
Nodding panicled brome-grass. Nat. of Europe.
Introduced 1776. H. K. i. 168.

At the time of flowering, the produce from a light sandy soil is—

		oz.		or lbs. per acre.		
Grass, 11 oz. The produce per acre - -		119790	0 =	7486	14	0
80 dr. of grass weigh when dry -	42 dr.	62889	12 =	3930	9	12
The produce of the space, ditto -	92·1⅜					
The weight lost by the produce of one acre in drying -				3556	4	4
64 dr. of grass afford of nutritive matter	3 dr.	5615	2 =	350	15	2
The produce of the space, ditto -	8·1					

This species, being strictly annual, affords no latter-math, which renders it comparatively of little value.

XIX. *Festuca cambrica*. Hudson. W. B. ii. p. 155.
Nat. of Britain.

At the time of flowering, the produce from a ligh sandy soil is—

		oz.		or lbs. per acre.		
Grass, 10 oz. The produce per acre - -		108900	0=	6806	4	0
80 dr. of grass weigh when dry -	34 dr.	46282	8=	2892	10	8
The produce of the space, ditto -	68					
The weight lost by the produce of one acre in drying			-	3913	9	8
64 dr. of grass afford of nutritive matter	2·1 dr.	3828	8=	239	4	8
The produce of the space, ditto -	5·2½					

This species is nearly allied to the *Festuca ovina,* from which it differs little, except that it is larger in every respect. The produce, and the nutritive matter which it affords, will be found superior to those given by the *F. ovina,* if they are brought into comparison.

XX. *Bromus diandrus.* Curt. Lond. Eng. Bot. 1006. Nat. of Britain.

At the time the grass is ripe in flower, the produce from a rich brown loam is —

Grass, 30 oz. The produce per acre - -		326700	0=	20418	12	0
80 dr. of grass weigh when dry -	34 dr.	138847	8=	8677	15	0
The produce of the space, ditto -	204					
The weight lost by the produce of one acre in drying			-	11740	13	0
64 dr. of grass afford of nutritive matter	3 dr.	15314	1=	957	2	1
The produce of the space, ditto -	22·2					

This species, like the preceding, is strictly annual; the above is therefore the produce for one year, which, if compored with that of the least productive of the perennial grasses, will be found inferior, and it must consequently be regarded as unworthy of culture.

XXI. *Poa angustifolia.* Wither. ii. p. 142. Narrow-leaved meadow-grass. Nat. of Britain.

At the time of flowering the produce from a brown loam is —

Grass, 27 oz. The produce per acre - - -		294030	=	18376	14	0
80 dr. of grass weigh when dry - -	34 dr.	124962	12=	7810	2	12
The produce of the space, ditto -	183·2⅗					
The weight lost by the produce of one acre in drying			-	10566	11	4
64 dr. of grass afford of nutritive matter	5 dr.	22886	11=	1430	6	11
The produce of the space, ditto .	33·3					

At the time the seed is ripe, the produce is —

		oz.		or lbs. per acre.		
Grass, 14 oz. The produce per acre - -		152460	0 =	9528	12	0
80 dr. of grass weigh when dry -	32 dr.	60984	0 =	3811	8	0
The produce of the space, ditto -	89·2⅖					
The weight lost by the produce of one acre in drying -				5717	4	0
64 dr. of grass afford of nutritive matter	5·1 dr.	12506	7 =	701	6	7
The produce of the space, ditto - -	18·1½					
The weight of nutritive matter which is lost by leaving the crop till the seed be ripe, exceeding one-third part of its value - - - - - - -				649	0	4

In the early growth of the leaves of this species of *Poa* there is a striking proof that early flowering in grasses is not always connected with the most abundant early produce of leaves. In this respect all the species which have already come under examination are greatly inferior to that now spoken of. Before the middle of April the leaves attain to the length of more than twelve inches, and are soft and succulent; in May, however, when the flower-stalks make their appearance, it is subject to the disease termed rust, which affects the whole plant; the consequence of which is manifest in the great deficiency of produce in the crop at the time the seed is ripe, being one-half less than at the time of the flowering of the grass. Though this disease begins in the straws, the leaves suffer most from its effects, being at the time the seed is ripe completely dried up: the straws, therefore, constitute the principal part of the crop for mowing, and they contain more nutritive matter in proportion than the leaves. This grass is evidently most valuable for permanent pasture, for which, in consequence of its superior, rapid, and early growth, and the disease beginning at the straws, nature seems to have designed it. The grasses which approach nearest to this in respect of early produce of leaves, are the *Poa fertilis, Dactylis glomerata, Phleum pratense, Alopecurus pratensis, Avena elatior,* and *Bromus littoreus,* all grasses of a coarser kind.

XXII. *Avena elatior.* Curtis, 112. Engl. Bot. 813.— Holcus avenaceus.

Tall oat-grass. Nat. of Britain.

At the time the seed is ripe, the produce is—

		oz.		or lbs. per acre.		
Grass, 24 oz. The produce per acre - -		261360	0=	16335	0	0
80 dr. of grass weigh when dry -	28 dr.	91475	14=	5717	3	14
The produce of the space, ditto -	$134\cdot1\frac{3}{5}$					
The weight lost by the produce of one acre in drying -				10617	12	2
64 dr. of grass afford of nutritive matter	1 dr.	4083	12=	255	3	12
The produce of the space, ditto -	6					

The produce of latter-math is —

Grass, 20 oz. The produce per acre - -		217800	0=	13612	8	0
64 dr. of grass afford of nutritive matter	1·1 dr.	4253	14=	265	13	14
The weight of nutritive matter which is afforded by the crop of the latter-math exceeding that afforded by the grass of the seed crop in proportion nearly as 26 to 25 - -				10	9	2

This grass sends forth flower-straws during the whole season; the latter-math contains nearly an equal number with the flowering crop. It is subject to the rust, but the disease does not make its appearance till after the period of flowering; it affects the whole plant, and at the time the seed is ripe the leaves and straws are withered and dry. This accounts for the superior value of the latter-math over the seed crop, and points out the propriety of taking the crop when the grass is in flower.

XXIII. *Poa elatior.* Curtis, 50.

Tall meadow-grass. Nat. of Scotland.

At the time of flowering, the produce from a rich clayey loam is —

Grass, 18 oz. The produce per acre - -		196020	0=	12251	4	0
80 dr. of grass weigh when dry -	28 dr.	60607	0=	4287	15	0
The produce of the space, ditto -	$100\cdot3\frac{2}{10}$					
64 dr. of grass afford of nutritive matter	3·2	10719	13=	669	15	13
The produce of the space, ditto -	15·3					
The weight lost by the produce of one acre in drying -				3617	15	3

The botanical characters of this grass are almost the same as those of the *Avena elatior*, differing in the want of the awns only. It has the essential character of the *Holci* (Florets male, and hermaphrodite: Calyx husks two valved, with two florets); and since the *Avena elatior* is now referred to that genus, this may with certainty be considered a variety of it.

XXIV. *Festuca duriuscula.* Engl. Bot. 470. W. B. ii. p. 153.

Hard fescue-grass. Nat. of Britain.

At the time of flowering, the produce from a light sandy loam is —

		oz.	or lbs. per acre.		
Grass, 27 oz. The produce per acre -		294030	0=18376	14	0
80 dr. of grass weigh when dry -	36 dr.	132313	8= 8269	9	0
The produce of the space, ditto -	194·1$\frac{3}{5}$				
The weight lost by the produce of one acre in drying -			10106	4	8
64 dr. of grass afford of nutritive matter	3·2dr.	16079	12= 1004	15	12
The produce of the space, ditto -	23·2$\frac{1}{2}$				

At the time the seed is ripe, the produce is —

Grass, 28 oz. The produce per acre - -		304920	0=19075	8	0
80 dr. of grass weigh when dry -	36 dr.	137214	0= 8575	14	0
The produce of the space, ditto -	201·2$\frac{2}{5}$				
The weight lost by the produce of one acre in drying -			10481	10	0
64 dr. of grass afford of nutritive matter	1·2 dr.	7146	9= 446	10	9
The produce of the space, ditto -	10·2				
The weight of nutritive matter which is lost by leaving the crop till the seed be ripe, exceeding one-half of its value - - - - - - -			558	5	3

The proportional value which the grass, at the time the seed is ripe, bears to that at the time of flowering, is as 6 to 14, nearly.

The produce of latter-math is —

Grass, 15 oz. The produce per acre - -		163350	0=10209	6	0
64 dr. of grass afford of nutritive matter	1·1dr.	3190	4= 199	6	4

The proportional value which the grass of the latter-math bears to that at the time of flowering, is as 5 to 14, and to that at the time the seed is ripe, 5 to 6.

The above particulars will confirm the favourable opinion which was given of this grass when speaking of the *Festuca hordiformis*, and *F. glabra*. Its produce in the spring is not very great, but of the finest quality, and at the time of flowering is considerable. If it be compared with those affecting similar soils, such as *Poa pratensis*, *Festuca ovina*, &c., either considered as a grass for hay, or permanent pasture, it will be found of greater value.

XXV. *Bromus erectus.* Engl. Bot 471. Host. G. A.
Upright perennial brome-grass. Nat. of Britain.

At the time of flowering, the produce from a rich sandy soil is—

		oz.	or lbs. per acre.		
Grass, 19 oz. The produce per acre -		206910 0=	12931	14	0
80 dr. of grass weigh when dry -	36 dr.	93109 8=	5819	5	8
The produce of the space, ditto -	136·3$\frac{1}{5}$				
The weight lost by the produce of one acre in drying -			7112	8	8
64 dr. of grass afford of nutritive matter	2·3 dr.	8890 10=	555	10	10
The produce of the space, ditto -	13·0$\frac{1}{4}$				

XXVI. *Milium effusum.* Curt. Lond. Engl. Bot. 1106.
Common millet-grass. Nat. of Britain.

At the time of flowering, the produce from a light sandy soil is —

Grass, 11 oz. 8 dr. The produce per acre -		196020 0=	12251	4	0
80 dr. of grass weigh when dry -	31 dr.	75957 12=	4747	5	12
The produce of the space, ditto -	111.2$\frac{2}{6}$				
64 dr. of grass afford of nutritive matter	1.3	5359 14=	334	15	14
The produce of the space ditto -	7·3$\frac{2}{4}$				

This species in its natural state seems confined to woods as its place of growth; but the trial that is here mentioned, confirms the opinion that it will grow and thrive in open exposed situations. It is remarkable for the lightness of the produce, in proportion to its bulk. It produces foliage early in the spring in considerable abundance; but its nutritive powers appear comparatively little.

XXVII. *Festuca Pratensis.* Engl. Bot. 1592. C. Lond.
Meadow fescue-grass. Nat. of Britain.

At the time of flowering, the produce from a bog soil, with coal ashes for manure is—

Grass, 20 oz. The produce per acre -		217800 0=	13612	8	0
80 dr. of grass weigh when dry -	38 dr.	103455 8=	6465	15	0
The produce of the space, ditto -	152				
The weight lost by the produce of one acre in drying -			7146	9	0
64 dr. of grass afford of nutritive matter	4·2dr.	15314 1=	957	2	1
The produce of the space, ditto -	22·2				

At the time the seed is ripe, the produce is —

	oz.	or lbs. per acre.		
Grass, 28 oz. The produce per acre -	304920	0=19057	8	0
80 dr. of grass weigh when dry - 32 dr. / The produce of the space, ditto - 179·0⅘	121968	0= 7623	0	0
The weight lost by the produce of one acre in drying -		11434	8	8
64 dr. of grass afford of nutritive matter 1·2dr. / The produce of the space, ditto 10·2	7146	0= 446	10	9
The weight of nutritive matter which is lost by leaving the crop till the seed be ripe, exceeding one-half of its value - - - - -		510	7	8

The value of the grass at the time the seed is ripe, is to that of the grass at the time of flowering, as 6 to 18.

The loss which is sustained by leaving the crop of this grass till the seed be ripe is very great. That it loses more of its weight in drying at this stage of growth, than at the time of flowering, perfectly agrees with the deficiency of nutritive matter in the seed crop, in proportion to that in the flowering crop: the straws being succulent in the former, they constitute the greatest part of the weight: but in the latter they are comparatively withered and dry; consequently the leaves constitute the greatest part of the weight. It may be observed here, that there is a great difference between straws or leaves that have been dried after they were cut in a succulent state, and those which are dried (if I may so express it) by nature while growing. The former retain all their nutritive powers; but the latter, if completely dry, very little, if any.

XXVIII. *Lolium perenne.* Engl. Bot. 315. Flo. Dan. 747.

Perennial rye-grass. Nat. of Britain.

At the time of flowering, the produce from a rich brown loam is —

Grass, 11 oz. 8 dr. The produce per acre -	125235	0=7827	3	0
80 dr. of grass weigh when dry - 34 dr. / The produce of the space, ditto - $78\frac{4}{10}$	53156	13=3322	4	13
The weight lost by the produce of one acre in drying -		4494	14	3
64 dr. of grass afford of nutritive matter 2·2dr. / The produce of the space, ditto - 7·0¾	4891	15= 305	11	15

At the time the seed is ripe, the produce is —

		oz.	or lbs. per acre.		
Grass, 22 oz. The produce per acre -		239580	0=14973	12	0
80 dr. of grass weigh when dry - 24 dr.					
The produce of the space, ditto - $105 \cdot 2\frac{2}{5}$		71874	0= 4492	2	0
The weight lost by the produce of one acre in drying -			10481	10	0
64 dr. of grass afford of nutritive matter 2·3 dr.					
The produce of the space, ditto - $15 \cdot 0\frac{2}{16}$		10294	7= 643	6	7
The weight of nutritive matter which is lost by taking the crop at the time of flowering, exceeding nearly one-half of its value, - - - - -			337	8	8

The proportional value which the grass at the time of flowering bears to that at the time the seed is ripe, is as 10 to 11.

The produce of the latter-math is —

Grass, 5 oz. The produce per acre -	54450	0=3403	2	0
64 dr. of grass afford of nutritive matter 1 dr.	850	12= 53	2	12

The proportional value which the grass of the latter-math bears to that at the time of flowering, is as 4 to 10, and to that at the time the seed is ripe, as 4 to 11.

XXIX. *Poa maritima.* Engl. Bot. 1140.

Sea meadow-grass. Nat. of Britain.

At the time of flowering, the produce from a light brown loam is —

Grass, 18 oz. The produce per acre -	196020	0=12251	4	0
80 dr. of grass weigh when dry - 32 dr.				
The produce of the space, ditto - $115 \cdot \frac{1}{5}$	78408	0= 4900	0	0
The weight lost by the produce of one acre in drying -		7350	4	0
64 dr. of grass afford of nutritive matter 4·2 dr.				
The produce of the space, ditto - 20·1	13782	0= 861	6	0

The produce of the latter-math is—

Grass, 18 oz. The produce per acre -	196020	0=12251	4	0
64 dr. of grass afford of nutritive matter 1 dr.	3062	13= 191	6	31

The proportional value which the grass of the latter-math bears to that at the time of flowering, is as 4 to 18.

XXX. *Cynosurus cristatus.* Engl. Bot. 316. Host. G. A. ii. t. 96.

Crested dog's-tail grass.

At the time of flowering, the produce from the brown loam, with manure, is—

		oz.	or lbs. per acre.		
Grass, 9 oz. The produce per acre -		98010	0=6125	10	0
80 dr. of grass weigh when dry -	24 dr.	29403	0=1837	11	0
The produce of the space, ditto -	43				
The weight lost by the produce of one acre in drying -			4287	15	0
64 dr. of grass afford of nutritive matter	4·1 dr.	6508	7= 406	12	7
The produce of the space, ditto -	$9·2\frac{1}{16}$				

At the time the seed is ripe, the produce is—

Grass, 18 oz. The produce per acre -		196020	0=122251	4	0
80 dr. of grass weigh when dry -	32 dr.	78408	0= 4900	0	0
The produce of the space, ditto -	$115·0\frac{8}{10}$				
The weight lost by the produce of one acre in drying -			7350	12	0
64 dr. of grass afford of nutritive matter	2·2 dr.	7657	0= 478	9	0
The produce of the space, ditto -	11·1				
The weight of nutritive matter which is lost by taking the crop at the time of flowering exceeding one-sixth of its value - - - - - -			71	12	9

XXXI. *Avena pratensis.* Engl. Bot. 1204. Fl. Dan. 1083.

Meadow oat-grass. Nat. of Britain.

At the time of flowering, the produce from a rich sandy loam is—

Grass, 10 oz. The produce per acre -		108900	0=6806	4	0
80 dr. of grass weigh when dry -	22 dr.	29947	8=1871	11	8
The produce of the space, ditto -	44				
The weight lost by the produce of one acre in drying -			4934	8	8
64 dr. of grass afford of nutritive matter	2·1 dr.	3828	8= 239	4	8
The produce of the space, ditto	$5·2\frac{1}{2}$				

At the time the seed is ripe, the produce is

Grass, 14 oz. The produce per acre -		152460	0=9528	12	0
80 dr. of grass weigh when dry -	24 dr.	45738	0=2858	10	0
The produce of the space, ditto -	$67·0\frac{4}{5}$				
The weight lost by the produce of one acre in drying -			6670	2	0
64 dr. of grass afford of nutritive matter	1 d.	2382	3= 148	14	3
The produce of the space, ditto -	3·2				
The weight of nutritive matter which is lost by leaving the crop till the seed be ripe, exceeding one-third part of its value			90	6	0

The proportional value which the crops, at the time the seed is ripe, bear to that at the time of flowering, is as 4 to 9.

XXXII. *Bromus multiflorus.* Engl. Bot. 1884. Host. G. A. i. t. 11.

Many-flowering brome-grass. Nat. of Britain.

At the time of flowering, the produce from a clayey loam is —

		oz.	or lbs. per acre.		
Grass, 33 oz. The produce per acre -		359370	0=22460	10	0
80 dr. of grass weigh when dry -	44 dr.	197653	8=12353	5	8
The produce of the space, ditto -	290·0$\frac{2}{5}$				
The weight lost by the produce of one acre in drying -			10107	4	8
64 dr. of grass afford of nutritive matter	5 dr.	28075	12= 1754	11	12
The produce of the space, ditto -	41·1				

This species is annual, and no valuable properties have as yet been discovered in the seed. It is only noticed only on account of its being frequently found in poor grass lands, and sometimes in meadows. It appears from the above particulars to possess nutritive powers equal to some of the best perennial kinds if taken when in flower; but if left till the seed be ripe (which, from its early growth, is frequently the case,) the crop is comparatively of no value, the leaves and straws being then completely dry.

XXXIII. *Festuca loliacea.* Curt. Lond. Engl. Bot. 1821.

Spiked fescue-grass. Nat. of Britain.

At the time of flowering, the produce from a brown rich loam is —

Grass, 24 oz. The produce per acre -		261360	0=16335	0	0
80 dr. of grass weigh when dry -	35 dr.	114345	0= 7146	9	0
The produce of the space, ditto -	168				
The weight lost by the produce of one acre in drying -			9188	7	0
64 dr. of grass afford of nutritive matter	3dr.	12251	4= 765	11	0
The produce of the space, ditto -	18				

At the time the seed is ripe, the produce is —

Grass, 16 oz. The produce per acre -		174240	0=10820	0	0
80 dr. of grass weigh when dry -	33 dr.	71874	9= 4492	2	0
The produce of the space, ditto -	105$\frac{3}{5}$				
The weight lost by the produce of one acre in drying -			6397	10	0
64 dr. of grass afford of nutritive matter	3·1 dr.	8848	2= 553	2	0
The produce of the space, ditto -	13				

The latter-math produce is—

		oz.	or lbs. per acre.		
Grass, 5 oz. The produce per acre	-	54450	0=3403	2	0
64 dr. of grass afford of nutritive matter 1·1 dr.		1063	7= 66	7	7
The weight of nutritive matter which is lost by leaving the crop till the seed be ripe, exceeding one-fourth part of its value - - - - -			212	11	0

The proportional value which the grass, at the time of flowering, bears to that at the time the seed is ripe, is as 12 to 13: and the value of the latter-math stands in proportion to that of the crop at the time of flowering, as 5 to 12, and to that of the crop taken at the time the seed is ripe, as 5 to 13.

This species of fescue greatly resembles the rye-grass, in habit and place of growth; it has excellencies which make it greatly superior to that grass, for the purposes of either hay or permanent pasture. This species seems to improve in produce in proportion to its age, which is directly the reverse of the *Lolium perenne.*

XXXIV. *Poa cristata.* Host. G. A. ii. t. 75.—Aira Cristata. Engl. Bot. 648.

Crested meadow-grass. Nat. of Britain.

At the time of flowering, the produce from a sandy loam is—

Grass, 16 oz. The produce per acre	-		174240	0=10890	0	0
80 dr. of grass weigh when dry	-	36 dr.	7848	0= 4900	8	0
The produce of the space, ditto	-	$115\frac{3}{16}$				
The weight lost by the produce of one acre in drying	-			5989	8	0
64 dr. of grass afford of nutritive matter		2 dr.	5445	0= 340	5	0
The produce of the space, ditto	-	8				

The produce of this species, and the nutritive matter that it affords, are equal to those of the *Festuca ovina* at the time the seed is ripe: they equally delight in dry soils. The greater bulk of grass in proportion to the weight, with the comparative coarseness of the foliage, render the *Poa cristata* inferior to the *Festuca ovina.*

XXXV. *Festuca myurus.* Engl. Bot. 1412. Host. G. A. ii. t. 93.

Wall fescue-grass. Nat. of Britain.

At the time of flowering, the produce from a light sandy soil is—

		oz.	or lbs. per acre		
Grass, 14 oz. The produce per acre -		152460	0= 9528	12	0
80 dr. of grass weigh when dry -	24 dr.	45738	0= 2858	10	0
The produce of the space, ditto -	$67\frac{2}{10}$				
The weight lost by the produce of one acre in drying -			6670	2	0
64 dr. of grass afford of nutritive matter 1·2 dr.		8573	4= 223	5	4
The produce of the space, ditto -	5·1				

This species is strictly annual; it is likewise subject to the rust: and the above being its whole produce for one year, it ranks as a very inferior grass.

XXXVI. *Aira flexuosa.* Engl. Bot. 1519. Host. G. A. ii. t. 43.

Waved mountain hair-grass. Nat. of Britain.

At the time of flowering, the produce from a heath soil is—

Grass, 12 oz. The produce per acre -		130680	0= 8167	8	0
80 dr. of grass weigh when dry -	31 dr.	50638	0= 3164	14	8
The produce of the space, ditto -	$74\frac{2}{5}$				
The weight lost by the produce of one acre in drying -			5002	9	8
64 dr. of grass afford of nutritive matter 1·2 dr.		3062	13= 191	6	13
The produce of the space, ditto -	4·2				

XXXVII. *Hordeum bulbosum.* Hort. Kew. i. p. 179.

Bulbous barley-grass. Nat. of Italy and the Levant. Introduced 1770, by Mons. Richard.

At the time of flowering, the produce from a clayey loam, with manure, is—

Grass, 35 oz. The produce per acre -		381150	0=23821	0	0
80 dr. of grass weigh when dry -	93 dr.	157224	0= 9826	8	6
The produce of the space, ditto -	231				
The weight lost by the produce of one acre in drying -			13994	7	10
64 dr. of grass afford of nutritive matter 3·2 dr.		20844	2= 1302	12	2
The produce of the space, ditto -	$30{\cdot}2\frac{3}{4}$				

XXXVIII. *Festuca calamaria.* Engl. Bot. 1005.

Reed-like fescue-grass. Nat. of Britain.

At the time of flowering, the produce from a clayey loam is—

Grass, 80 oz. The produce per acre -		871200	0=54450	0	0
80 dr. of grass weigh when dry -	28 dr.	304920	0=19057	8	0
The produce of the space, ditto -	448				
The weight lost by the produce of one acre in drying -			35392	8	0
64 dr. of grass afford of nutritive matter 4·2 dr.		61256	4= 3828	8	4
The produce of the space, ditto -	90				

At the time the seed is ripe, the produce is—

		oz.	or lbs. per acre.		
Grass, 75 oz. The produce per acre -		816750	0=51046	14	0
80 dr. of grass weigh when dry - 19 dr.	The produce of the space, ditto - 283	193978	2=12123	10	0
The weight lost by the produce of one acre in drying -			38223	4	0
64 dr. of grass afford of nutritive matter 3 dr.	The produce of the space, ditto - 56·1	38285	2= 2392	13	2
The weight of nutritive matter which is lost by leaving the crop till the seed is ripe, being nearly one-third part of its value - - - -			1435	11	2

The proportional value which the grass, at the time the seed is ripe, bears to that at the time of flowering, is as 12 to 18.

This grass, as has already been remarked, produces a fine early foliage in the spring. The produce is very great, and its nutritive powers are considerable. It appears, from the above particulars, to be best adapted for hay. A very singular disease attacks, and sometimes nearly destroys, the seed of this grass: the cause of this disease seems to be unknown; it is denominated Clavus by some; it appears by the seed swelling to three times its usual size in length and thickness, and the want of the carcle. Dr. Willdenow describes two distinct species of it: 1st, the simple clavus, which is mealy and of a dark colour, without any smell or taste; 2dly, the malignant clavus, which is violet blue, or blackish, and internally too has a bluish colour, a fœtid smell, and a sharp pungent taste. Bread made from grain affected with this last species is of a bluish colour; when eaten, produces cramps and giddiness.

XXXIX. *Bromus littoreus.* Host. G. A. P. vii. t. 8.
Sea-side brome-grass. Nat. of Germany: grows on the banks of the Danube and other rivers.

At the time of flowering, the produce from a clayey loam is—

Grass, 61 oz. The produce per acre -		664290	0=41518	2	0
80 dr. of grass weigh when dry - 41 dr.	The produce of the space, ditto - $500\frac{2}{10}$	340448	10=21278	0	10
The weight lost by the produce of one acre in drying -			20540	1	6
64 dr. of grass afford of nutritive matter 1·2 dr.	The produce of the space, ditto - $22·3\frac{1}{2}$	15567	4= 973	1	4

At the time the seed is ripe, the produce is—

		oz.	or lbs. per acre.		
Grass, 56 oz. The produce per acre -		609840	0=38115	0	0
80 dr. of grass weigh when dry -	32 dr.	243936	0=15246	0	0
The produce of the space, ditto -	$358\frac{1}{6}$				
The weight lost by the produce of one acre in drying -			22869	0	0
64 dr. of grass afford of nutritive matter	3·2 dr.	33950	0= 2084	6	10
The produce of the space, ditto -	196				
The weight of nutritive matter which is lost by taking the crop at the time of flowering, exceeding one-half of its value - - - -			1111	5	6

The proportional value which the grass, at the time of flowering, bears to that at the time the seed is ripe, is as 6 to 14.

This species greatly resembles the preceding in habit and manner of growth, but is inferior to it in value, which is evident from the deficiency of its produce, and of the nutritive matter afforded by it. The whole plant is likewise coarser, and of greater bulk in proportion to its weight. The seed is affected with the same disease which destroys that of the former species.

XL. *Festuca elatior.* Engl. Bot. 1593. Host. G. A. ii. t. 79.

Tall fescue-grass. Nat. of Britain.

At the time of flowering, the produce from a black rich loam is—

Grass, 75 oz. The produce per acre -		816750	0=51046	14	0
80 dr. of grass weigh when dry -	28 dr.	285862	8=17866	6	8
The produce of the space, ditto -	420				
The weight which is lost by the produce of one acre in drying			33180	7	8
64 dr. of grass afford of nutritive matter	5 dr.	63808	9= 3988	0	9
The produce of the space, ditto -	93·3				

At the time the seed is ripe, the produce is—

Grass, 75 oz. The produce per acre -		816750	0=51046	14	0
80 dr. of grass weigh when dry -	28 dr.	285862	8=17866	6	0
The produce of the space, ditto -	420				
The weight lost by the produce of one acre in drying			33180	7	8
64 dr. of grass afford of nutritive matter	3 dr.	38285	2= 2392	13	2
The produce of the space, ditto -	56·1				
The weight of nutritive matter which is lost by leaving the crop till the seed be ripe, exceeding one-third part of its value - - - -			1595	3	7

The proportional value which the grass, at the time

the seed is ripe, bears to that at the time of flowering, is as 12 to 20.

The produce of the latter-math is—

		oz.	or lbs. per acre.		
Grass, 23 oz. The produce per acre	-	250470	0=15654	6	0
64 dr. of grass afford of nutritive matter 4 dr.		15054	6= 978	6	6

The proportional value which the grass of the latter-math bears to that of the crop, is as 16 to 20; and to that at the time the seed is ripe, as 12 to 16 inverse.

This species of fescue is closely allied to the *Festuca pratensis*, from which it differs in little, except that it is larger in every respect. The produce is nearly three times that of the *F. pratensis*, and the nutritive powers of the grass are superior, in direct proportion, as 6 to 8.

XLI. *Nardus stricta.* Engl. Bot. 290. Host. G. A. ii. t. 4.

Upright mat-grass. Nat. of Britain.

At the time the seed is ripe, the produce is—

Grass, 9 oz. The produce per acre	-	98010	0= 6125	10	0
80 dr. of grass weigh when dry - 32 dr. / The produce of the space, ditto - 57·2⅖		39204	0= 2450	4	0
The weight lost by the produce of one acre in drying		-	3675	6	0
64 dr. of grass afford of nutritive matter 2·1 dr. / The produce of the space, ditto - 5·0⅕		3445	10= 215	5	10

XLII. *Triticum, Sp.*

Wheat-grass.

At the time of flowering, the produce from a rich sandy loam is—

Grass, 18 oz. The produce per acre	-	196020	0=12251	4	0
80 dr. of grass weigh when dry - 32 dr. / The produce of the space, ditto - 115⅕		78408	0= 4900	8	0
The weight lost by the produce of one acre in drying		-	7350	12	0
64 dr. of grass afford of nutritive matter 2·2 dr. / The produce of the space, ditto - 11·1		7657	0= 478	9	0

XLIII. *Festuca fluitans.* Curt. Lond. Engl. Bot. 1520. Poa fluitans.

Floating fescue-grass. Nat. of Britain.

At the time of flowering, the produce from a strong tenacious clay is—

		oz.		or lbs. per acre.		
Grass, 20 oz. The produce per acre	-	217800	0=	13612	8	0
80 dr. of grass weigh when dry -	24 dr.	65340	0=	4083	12	0
The produce of the space, ditto -	96					
The weight lost by the produce of one acre in drying	-			9528	12	0
64 dr. of grass afford of nutritive matter	1·3 dr.	5955	0=	372	3	7
The produce of the space, ditto -	8·3					

The above produce was taken from grass that had occupied the ground for four years, during which time it had increased every year; it therefore appears, contrary to what some have supposed, to be capable of being cultivated in perennial pastures.

XLIV. *Holcus lanatus.* Curt. Lond. Fl. Dan. 1811.

Meadow soft grass. Yorkshire grass. Nat. of Britain.

At the time of flowering, the produce from a strong clayey loam is —

Grass, 28 oz. The produce per acre	-	304920	0=	19057	8	0
80 dr. of grass weigh when dry -	26 dr.	106585	14=	6661	9	14
The produce of the space, ditto -	$157{\cdot}2\frac{2}{5}$					
The weight lost by the produce of one acre in drying	-			12395	14	2
64 dr. of grass afford of nutritive matter	4 dr.	19057	8=	1191	1	8
The produce of the space, ditto -	28					

At the time the seed is ripe, the produce is —

Grass, 28 oz. The produce per acre	-	304920	0=	19057	8	0
80 dr. of grass weigh when dry -	16 dr.	60984	0=	3811	8	0
The produce of the space, ditto -	$89{\cdot}2\frac{2}{5}$					
The weight lost by the produce of one acre in drying	-			15246	0	0
64 dr. of grass afford of nutritive matter	2·3 dr.	13102	0=	818	14	0
The produce of the space, ditto -	19·1					
The weight of nutritive matter which is lost by leaving the crop till the seed is ripe, exceeding one-third part of its value - - - - - -				372	3	8

The proportional value which the grass, at the time the seed is ripe, bears to that at the time of flowering, is as 11 to 12.

XLV. *Festuca dumetorum.* Flo. Dan. 700.

Pubescent fescue-grass. Nat. of Britain.

At the time of flowering, the produce from a black sandy loam is —

		oz.	or lbs. per acre.		
Grass, 16 oz. The produce per acre -		174240	0=10890	0	0
80 dr. of grass weigh when dry -	40 dr.	87120	0= 5445	0	0
The produce of the space, ditto -	128				
The weight lost by the produce of one acre in drying		-	5445	0	0
64 dr. of grass afford of nutritive matter	1 dr.	2722	8= 170	2	8
The produce of the space, ditto -	4				

XLVI. *Poa fertilis.* Host. G. A.

Fertile meadow-grass. Nat. of Germany.

At the time of flowering, the produce from a clayey loam is—

Grass, 22 oz. The produce per acre -		239580	0=14973	12	0
80 dr. of grass weigh when dry -	42 dr.	125779	8= 7861	3	8
The produce of the space, ditto -	184⅘				
The weight lost by the produce of one acre in drying		-	7111	8	8
64dr. of grass afford of nutritive matter	4 2 dr.	16845	7= 1052	13	7
The produce of the space, ditto -	24·3				

If the nutritive powers and produce of this species be compared with any other of the same family, or such as resemble it in habit and the soil which it affects, a superiority will be found, which ranks this as one of the most valuable grasses; next to the *Poa angustifolia*, it produces the greatest abundance of early foliage, of the best quality, which fully compensates for the comparative lateness of flowering.

XLVII. *Arundo colorata.* Hort. Kew. i. p. 174. Engl. Bot. 402. Phalaris arundinacea.

Striped-leaved reed-grass. Nat. of Britain.

At the time of flowering, the produce from a black sandy loam is—

Grass, 40 oz. The produce per acre -		435600	0=27225	0	0
80 dr. of grass weigh when dry -	36 dr.	196020	0=12251	4	0
The produce of the space, ditto -	288				
64 dr. of grass afford of nutritive matter	4	27225	0= 1701	9	0
The produce of the space, ditto -	40				

The strong nutritive powers which this grass possesses recommend it to the notice of occupiers of strong clayey lands which cannot be drained. Its produce is great, and the foliage will not be denominated coarse, if compared with those which afford a produce equal in quantity.

XVLIII. *Trifolium pratense.* W. Bot. iii. p. 137. Broad-leaved cultivated clover. Nat. of Britain.

At the time the seed is ripe, the produce from a rich clayey loam is—

Grass, 72 oz. The produce per acre -	784080	0=49005	0	0
80 dr. of grass weigh when dry - 20 dr. The produce of the space, ditto - 288	196020	0=12251	0	0
The weight lost by the produce of one acre in drying -		3675	4	0
64 dr. of grass afford of nutritive matter 2·2dr. The produce of the space, ditto - 45	30628	2= 1914	4	2

If the weight which is lost by the produce of this species of clover, in drying, be compared with that of many of the natural grasses, its inferior value for the purpose of hay, compared to its value for green food or pasture, will appear; for it is certain that the difficulty of making good hay increases in proportion with the quantity of superfluous moisture which the grass may contain. Its value for green food or pasture may further be seen by comparing its nutritive powers with those manifested by other plants generally esteemed best for this purpose.

Trifolium pratense (as above) affords of nutritive matter - - - - 2·2 dr.

XLIX. *Trifolium repens* (white clover) from an equal quantity of grass - - 2·0

L. Ditto, variety with brown leaves, ditto - 2·2

The grass of the *T. pratense*, therefore, exceeds in value that of the *T. repens* by a proportion as 8 to 10; but it is of equal proportional value with the brown variety.

LI. *Burnet* (Poterium sanguisorba) affords of nutritive matter - - - - 2·2 dr.

LII. *Brunias orientalis* (a newly introduced plant) ditto - - - - - 2·2

The proportional value of these two last, and of the *T. pratense*, and the brown-leaved variety of *T. repens*, are equal: they exceed the *T. repens* as 8 to 10.

The comparative produce of these four last-mentioned species per acre has not been ascertained.

LIII. *Trifolium macrorhizum.*

Log-rooted clover. Nat. of Hungary.

At the time the seed is ripe, the produce from a rich clayey loam is—

		oz.	or lbs. per acre.		
Grass, 144 oz. The produce per acre -		1568160	0=98010	0	0
80 dr. of grass weigh when dry -	34 dr.	666468	0=41654	4	0
The produce of the space, ditto -	$979\frac{1}{5}$				
The weight lost by the produce of one acre in drying -			56355	12	0
64 dr. of grass afford of nutritive matter	2·3 dr.	67381	14= 4211	5	14
The produce of the space, ditto -	99				

The root of this species of clover is biennial; it penetrates to a great depth in the ground, and is in consequence little affected by the extremes of wet or dry weather. It requires good shelter and a deep soil. The produce, when compared to that of others that are allied to it in habit and place of growth, proves greatly superior. The following particulars, some of which refer to results stated in the next two pages, will make this manifest:—

		lbs.
Trifolium pratense, Broad-leaved clover	Produces per acre, Grass - -	49005
	Ditto, Hay - - -	12251
	Affords, ditto, of nutritive matter -	1914
Medicago sativa, Lucern. From a soil of the like nature	Produces per acre, Grass - -	70785
	Ditto, Hay - - -	28314
	Affords of nutritive matter - -	1659
Hedysarum onobrichis, Saintfoin	Produces per acre, Grass - -	8848
	Ditto, Hay - - -	3536
	Affords of nutritive matter - -	314

The weight of nutritive matter afforded by the produce of the *T. macrorhizum,* exceeding that of the *T. pratense,* in proportion nearly as 7 to 15 - - - - - - - 2297

The proportional value of the grass of *T. pratense,* to that of *T. macrorhizum,* is 10 to 11.

The weight of nutritive matter afforded by the *T. macrorhizum,* exceeding that of the *Medicago sativa,* in proportion nearly as 13 to 33 - - - - - - - 2552

The proportional value of the grass is 11 to 6.

The weight of nutritive matter which is afforded by the produce of the *T. macrorhizum,* exceeding that of the *Hedysarum onobrychis,* in proportion as 5 to 67 - - - - - - 3897

The proportional value of the grass, like that of the *T. pratense*, is as 11 to 10.

The produce of each of the above-mentioned species was taken from a similar soil, and in the same situation; the conclusions must therefore be considered positive, with respect to such soils only. It is evident that more than twice the quantity of nutritive matter is afforded by the produce of one acre of the *T. macrorhizum*, than from the produce of an equal space covered by the *T. pratense*. Its short duration in the soil (for, if sown early in the autumn, on a rich light soil, it is only an annual plant,) renders it fit only for green-food or hay; this, in some measure, lessens its value, when compared with the *T. pratense*. It possesses the essential property of affording abundance of good seed; and if the ground be kept clear of weeds, it sows itself, vegetates, and grows rapidly, without covering-in, or any operation whatever. For four years it has propagated itself in this manner, on the space of ground which it now occupies, and from which this statement of its comparative value is made. The produce of lucern in grass, comes nearer to this species in quantity; but it is greatly deficient in nutritive matter, as much as 13 to 33. The long continuance of lucern in the soil, is therefere the only merit which it possesses above the two last-mentioned species; and when that is the object of the cultivator, it will, of necessity, have the preference.

The value of the grass of saintfoin, is equal to that of the *T. pratense;* and proportionally less than that of the *Trifolium macrorhizum*, as 10 to 11. The quantity of grass is very small; and on soils, of the nature above described, it is doubtless inferior. However, from the superior value of the grass, on dry hilly situations, or chalky soils, it may in such situations possibly be their superior in every respect.

LIV. *Medicago Sativa.* Wither. B. iii. p. 643.
Lucern. Nat. of Brit.

At the time the seed is ripe, the produce from a rich clayey loam is—

		oz.	or lbs. per acre.		
Grass, 104 oz. The produce per acre -		1132560	0=70785	0	0
80 dr. of grass weigh when dry -	32 dr.	453024	0=28314	0	0
The produce of the space, ditto -	665·2⅗				
The weight lost by the produce of one acre in drying -			42471	0	0
64 dr. of grass afford of nutritive matter	1·2 dr.	26544	9= 7569	0	6
The produce ot the space, ditto -	39				

LV. *Hedysarum onobrychis.* Wither. iii. p. 628.

Saintfoin. Nat. of Britain.

At the time the seed is ripe, the produce from a rich clayey loam is—

Grass, 13 oz. The produce per acre -		141570	0= 8848	2	0
80 dr. of grass weigh when dry -	32 dr.	56628	0= 3539	4	0
The produce of the space, ditto -	83⅓				
The weight lost by the produce of one acre in drying -			5308	14	0
64 dr. of grass afford of nutritive matter	2·2 dr.	5530	1= 345	10	1
The produce of the space, ditto - -	8·0½				

LVI. *Hordeum pratense.* Engl. Bot. 409. Host. G. A. i. t. 33.

Meadow barley-grass. Nat. of Britain.

At the time of flowering, the produce from a brown loam with manure, is—

Grass, 12 oz. The produce per acre -		130680	0= 8167	8	0
80 dr. of grass weigh when dry -	32 dr.	52272	0= 3267	0	0
The produce of the space, ditto -	67·1				
The weight lost by the produce of one acre in drying -			4900	8	0
64 dr. of grass afford of nutritive matter	3·3 dr.	7657	0= 478	9	0
The produce of the space, ditto -	11·1				

LVII. *Poa compressa.* Engl. Bot. 365.

Flat-stalked meadow-grass. Nat. of Britain.

At the time of flowering, the produce from a gravelly soil, with manure, is—

Grass, 5 oz. The produce per acre - -		54450	0= 3403	2	0
80 dr. of grass weigh when dry -	34 dr.	23141	4= 1446	5	4
The produce of the space, ditto -	34				
The weight lost by the produce of one acre in drying -			1956	12	12
64 dr. of grass afford of nutritive matter	5 dr.	4253	14= 265	13	14
The produce of the space, ditto -	6·1				

The specific characters of this species, are much the same as those of the *Poa fertilis,* differing in the compressed figure of the straws, and creeping root only. If

the produce was of magnitude, it would be one of the most valuable grasses; for it produces foliage early in the spring, and possesses strong nutritive powers.

LVIII. *Poa aquatica.* Curt. Lond. Engl. Bot. 1315.
Reed meadow-grass. Nat. of Britain.

At the time of flowering, the produce from a strong tenacious clay is—

		oz.	or lbs. per acre.		
Grass, 186 oz. The produce per acre	-	2025540	=126596	4	0
80 dr. of grass weigh when dry -	48 dr.	1215324	= 75957	12	0
The produce of the space, ditto -	$1785{\cdot}2\frac{2}{16}$				
The weight lost by the produce of one acre in drying		-	50638	8	0
64 dr. of grass afford of nutritive matter	2·2 dr.	79122	= 4945	2	10
The produce of the space, ditto -	116·1				

LIX. *Aira aquatica.* Curt. Lond. Engl. Bot. 1557.
Water hair-grass. Nat. of Britain.

At the time of flowering, the produce from water is—

Grass, 16 oz. The produce per acre	-	174240 0	=10890	0	0
80 dr. of grass weigh when dry -	24 dr.	52272 0	= 3267	0	0
The produce of the space, ditto -	$76{\cdot}3\frac{1}{16}$				
The weight lost by the produce of one acre in drying		-	7623	0	0
64 dr. of grass afford of nutritive matter	2·1 dr.	6122 10	= 382	13	10
The produce of the space, ditto -	9				

LX. *Bromus cristatus.* Triticum cristatum, H. G. A. 2. t. 24. Secale prostratum. Jacquin. Nat. of Germany.

At the time of flowering, the produce from a clayey loam is—

Grass, 13 oz. The produce per acre	-	141570 0	= 8848	0	0
80 dr. of grass weigh when dry -	32 dr.	56628 0	= 3539	4	0
The produce of the space, ditto -	83·1				
The weight lost by the produce of one acre in drying		-	5308	14	0
64 dr. of grass afford of nutritive matter	2·2 dr.	5530 1	= 345	10	0
The produce of the space, ditto -	$8{\cdot}0\frac{2}{16}$				

LXI. *Elymus Sibiricus.* Hort. K. i. p. 176. Cult. 1758. by Mr. P. Millar.
Siberian lyme-grass. Nat. of Siberia.

At the time of flowering, the produce from a sandy loam, with manure, is—

		oz.		or lbs. per acre.		
Grass, 24 oz. The produce per acre	-	261360	0=	16335	0	0
80 dr. of grass weigh when dry -	28 dr.	91476	0=	5717	4	0
The produce of the space, ditto -	134·1$\frac{3}{5}$					
The weight lost by the produce of one acre in drying	-			10617	12	0
64 dr. of grass afford of nutritive matter	2·1 dr.	9188	7=	511	7	0
The produce of the space, ditto -	13·2					

LXII. *Aira cæspitosa.* Host. G. A. ii. t. 42. Engl. Bot. 1557.

Turfy hair-grass. Nat. of Britain.

At the time the seed is ripe, the produce from a strong tenacious clay is—

Grass, 15 oz. The produce per acre	-	163350	6=	10209	6	0
80 dr. of grass weigh when dry -	26 dr.	53088	12=	3318	0	12
The produce of the space, ditto -	135$\frac{1}{5}$					
The weight lost by the produce of one acre in drying	-			6891	5	4
64 dr. of grass afford of nutritive matter	2 dr.	5104	11=	319	0	1
The produce of the space, ditto -	7·2					

LXIII. *Hordeum murinum.* Curt. Lond. Engl. Bot. 1971.

Wall barley-grass. Way Bennet. Nat. of Britain.

At the time of flowering, the produce from a clayey loam is—

Grass, 18 oz. The produce per acre	-	196020	0=	12251	4	0
80 dr. of grass weigh when dry -	28 dr.	68607	0=	4287	15	0
The produce of the space, ditto -	100·3$\frac{3}{5}$					
The weight lost by the produce of one acre in drying	-			7963	5	0
64 dr. of grass afford of nutritive matter	3 dr.	2679	15=	167	7	15
The produce of the space, ditto -	3·3$\frac{3}{16}$					

LXIV. *Avena flavescens.* Curt. Lond. Engl. Bot. 952.

Yellow oat-grass. Nat of Britain.

At the time of flowering, the produce from a clayey loam is—

Grass, 12 oz. The produce per acre	-	130680	0=	8167	8	0
80 dr. of grass weigh when dry -	28 dr.	45738	0=	2858	10	0
The produce of the space, ditto -	67·1					
The weight lost by the produce of one acre in drying	-			5308	14	0
64 dr. of grass afford of nutritive matter	3·3 dr.	7657	0=	748	9	0
The produce of the space, ditto -	11·1					

At the time the seed is ripe, the produce is—

		oz.	or lbs. per acre.		
Grass, 18 oz. The produce per acre -		196020 0	=12251	4	0
80 dr. of grass weigh when dry -	32 dr.	78408 0	= 4900	8	0
The produce of the space, ditto -	$115{\cdot}0\frac{4}{5}$				
The weight lost by the produce of one acre in drying -			7350	12	0
64 dr. of grass afford of nutritive matter	2·1 dr.	6891 5	= 430	11	5
The produce of the space, ditto -	$10{\cdot}0\frac{1}{2}$				
The weight of nutritive matter which is lost, if the crop be left till the seed be ripe, exceeding one-tenth part of its value - - - -			47	13	11

The proportional value which the grass at the time the seed is ripe bears to that at the time of flowering, is as 9 to 15.

The produce of latter-math is—

Grass, 6 oz. The produce per acre -	65340 0	= 4083	12	0
64 dr. of grass afford of nutritive matter 1·1 dr.	1276 2	= 79	12	2

The proportional value which the grass of the latter-math bears to that at the time of flowering, is as 5 to 15; and to that at the time the seed is ripe, as 5 to 9.

This species is pretty generally cultivated in many parts of this kingdom; and it appears from the above details to be a valuable grass, though inferior to many others.

LXV. *Bromus sterilis.* Engl. Bot. 1030. Hos. G. A. i. t. 16.

Barren brome-grass. Nat. of Britain.

At the time of flowering, the produce from a sandy soil is—

Grass, 44 oz. The produce per acre -		479160 0	=29947	8	0
80 dr. of grass weigh when dry -	45 dr.	269527 8	=16845	7	8
The produce of the space, ditto -	396				
The weight lost by the produce of one acre in drying -			13102	0	8
64 dr. of grass afford of nutritive matter	5 dr.	37434 6	=2339	10	0
The produce of the space, ditto -	55				

64 dr. of the flowers afford of nutritive matter 2·2 dr. The nutritive powers of the straws and leaves are, therefore, more than twice as great as those of the flowers. This species, being strictly annual, is of comparatively little value. The above particulars show that it has very considerable nutritive powers, more than its name would imply, if taken at the time of flowering; but if

left till the seed be ripe, it is, like all other annuals, comparatively of no value.

LXVI. *Holcus mollis.* Curt. Lond. Wither. B. ii. p. 134. Creeping soft-grass. Nat. of Britain.

At the time of flowering, the produce from a sandy soil is—

		oz.	or lbs. per acre.		
Grass, 50 oz. The produce per acre	-	544500	0=34031	4	0
80 dr. of grass weigh when dry - 32 dr. / The produce of the space, ditto - 320		217800	0=13612	8	0
The weight lost by the produce of one acre in drying	-		20418	12	0
64 dr. of grass afford of nutritive matter 4·2 dr. / The produce of the space, ditto - 56·1		38285	2= 2392	13	2

At the time the seed is ripe, the produce is—

Grass, 31 oz. The produce per acre	-	337590	0=21099	6	0
80 dr. of grass weigh when dry - 32 dr. / The produce of the space, ditto - 198·1$\frac{3}{5}$		135036	0= 8439	12	0
The weight lost by the produce of one acre in drying	-		12659	10	0
64 dr. of grass afford of nutritive matter 3·2 dr. / The produce of the space, ditto - 27·0$\frac{2}{5}$		18461	15= 1153	13	15
The weight of nutritive matter which is lost by leaving the crop till the seed be ripe, being nearly one-half of its value - - - -			1238	15	3

64 dr. of the roots afford of nutritive matter 5·2 dr.

The proportional value which the grass at the time the seed is ripe bears to that at the time of flowering, is as 14 to 18.

The above details prove this grass to have merits which, if compared with those of other species, rank it with some of the best grasses. The small loss of weight which it sustains in drying might be expected from the nature of the substance of the grass; and the loss of weight at each period is equal. The grass affords the greatest quantity of nutritive matter when in flower, which makes it rank as one of those best adapted for hay.

LXVII. *Poa fertilis.* Var. B. Host. G. A. The species. Fertile meadow-grass. Variety 1. Nat. of Germany.

At the time of flowering, the produce from a brown sandy loam is—

		oz.	or lbs. per acre.
Grass, 23 oz. The produce per acre -		250470 0=	15654 6 0
80 dr. of grass weigh when dry -	34 dr.	106448 0=	6653 8 0
The produce of the space, ditto -	156$\frac{2}{5}$		
The weight lost by the produce of one acre in drying -			9000 14 0
64 dr. of grass afford of nutritive matter	3 dr.	11740 12=	733 12 12
The produce of the space, ditto -	17·1		

At the time the seed is ripe, the produce is—

Grass, 22 oz. The produce per acre -		239580 0=	14978 12 0
80 dr. of grass weigh when dry -	44 dr.	131769 0=	8235 9 0
The produce of the space, ditto -	193·2		
The weight lost by the produce of one acre in drying -			6733 3 0
64 dr. of grass afford of nutritive matter	5 dr.	18717 3=	1169 13 3
The produce of the space, ditto -	27·2		
The weight of nutritive matter which is lost by taking the crop at the time of flowering, exceeding one-third part of its value, is - - -			436 1 3

The proportional value which the grass at the time of flowering bears to that at the time the seed is ripe, is as 6 to 20.

The produce of latter-math is—

Grass, 7 oz. The produce per acre -		76230 0=	4764 6 0
64 dr. of grass afford of nutritive matter	1·2 dr.	1786 10=	111 10 10

The proportional value which the grass of the latter-math bears to that at the time of flowering, is as 6 to 12; and to that at the time the seed is ripe, as 6 to 20.

LXVIII. *Cynosurus erucæformis.* Beckmannia erucæformis. Host. G. A. iii. t. 6.

Linear-spiked dog's-tail grass. Nat. of Germany.

At the time the seed is ripe, the produce is—

Grass, 18 oz. The produce per acre -		196020 0=	12251 4 0
80 dr. of grass weigh when dry -	36 dr.	88209 0=	5513 1 0
The produce of the space, ditto -	129·2$\frac{2}{5}$		
The weight lost by the produce of one acre in drying -			6738 3 0
64 dr. of grass afford of nutritive matter	3·1 dr.	9954 2=	622 2 2
The produce of the space, ditto -	14·2$\frac{3}{4}$		

LXIX. *Phleum nodosum.* With. B. ii. p. 118.

Bulbous-stalked cat's-tail grass. Nat. of Britain.

At the time of flowering, the produce from a clayey loam is—

		oz.	or lbs. per acre.		
Grass, 18 oz. The produce per acre -		196020	=12251	4	0
80 dr. of grass weigh when dry -	38 dr.	93109 8=	5819	5	8
The produce of the space, ditto -	$136\frac{4}{5}$				
The weight lost by the produce of one acre in drying -			6431	14	0
64 dr. of grass afford of nutritive matter	2·2 dr.	7657 0=	478	9	0
The produce of the space, ditto -	11·1				

This grass is inferior in many respects to the *Phleum pratense.* It is sparingly found in meadows. From the number of bulbs which grow out of the straws, a greater portion of nutritive matter might have been expected. This seems to prove that these bulbs do not form so valuable a part of the plant as the joints, which are so conspicuous in the *Phleum pratense,* the nutritive powers of which exceed those of the *P. nodosum,* as 8 to 28.

LXX. *Phleum pratense.* Wither. ii. p. 117.

Meadow cat's-tail grass. Nat. of Britain.

At the time of flowering, the produce from a clayey loam is—

Grass, 60 oz. The produce per acre -		653400 0=	40837	8	0
80 dr. of grass weigh when dry -	34 dr.	277695 0=	17355	15	0
The produce of the space, ditto -	408				
The weight lost by the produce of one acre in drying -			23481	9	0
65 dr. of grass afford of nutritive matter	2·2 dr.	25523 7=	1595	3	0
The produce of the space, ditto -	37·2				
The weight of nutritive matter which is lost by leaving the crop till the seed be ripe, exceeding one-half of its value - - - - - -			2073	11	0

At the time the seed is ripe, the produce is—

Grass, 60 oz. The produce per acre -		653400 0=	40837	8	0
80 dr. of grass weigh when dry -	38 dr.	310365 0=	19397	13	0
The produce of the space, ditto -	456				
The weight lost by the produce of one acre in drying -			21439	11	0
64 dr. of grass afford of nutritive matter	5·3 dr.	58703 14=	3668	15	14
The produce of the space, ditto -	86·1				

The latter-math produce is—

Grass, 14 oz. The produce per acre -		152460 0=	9528	12	0
64 dr. of grass afford of nutritive matter	2 dr.	4764 6=	297	12	6

64 dr. of the straws afford of nutritive matter 7 dr. The nutritive powers of the straws simply, therefore, exceed those of the leaves, in proportion as 28 to 8; and the grass, at the time of flowering, to that at the time the

seed is ripe, as 10 to 23; and the latter-math, to the grass of the flowering crop, as 8 to 10.

The comparative merits of this grass will appear from the above particulars to be very great; to which may be added the abundance of fine foliage that it produces early in the spring. In this respect it is inferior to the *Poa fertilis* and *Poa angustifolia* only. The value of the straws at the time the seed is ripe exceeds that of the grass at the time of flowering, as 28 to 10; a circumstance which increases its value above many others; for, by this property, its valuable early foliage may be cropped to an advanced period of the season without injury to the crop of hay, which in other grasses which send forth their flowering straws early in the season would cause a loss of nearly one-half of the value of the crop, as is clearly proved by former examples; and this property of the straws makes the plant peculiarly valuable for the purpose of hay.

LXXI. *Phleum pratense.* Var. minor. Wither. B. ii. p. 118. Var. 1.

Meadow cat's-tail grass. Var. Smaller. Nat. of Britain.

At the time of ripening the seed, the produce from a clayey loam is—

		oz.	or lbs. per acre.		
Grass, 40 oz. The produce per acre -		435600	0=27225	0	0
80 dr. of grass weigh when dry -	34 dr.	185130	0=11570	10	0
The produce of the space, ditto -	272				
The weight lost by the produce of one acre in drying -			1654	6	0
64 dr. of grass afford of nutritive matter	2·3 dr.	1817	3= 1169	13	3
The produce of the space, ditto -	272				

The latter-math produce is—

Grass, 14 oz. The produce per acre -	152460	0=9528	12	0
64 dr. of grass afford of nutritive matter 1·2 dr.	3573	4= 223	5	4

LXXII. *Elymus arenarius.* Engl. Bot. 1672.

Upright sea lyme-grass. Nat. of Britain.

At the time the seed is ripe, the produce from a clayey loam is—

		oz.	or lbs. per acre.		
Grass, 64 oz. The produce per acre -		696960	0=43560	0	0
80 dr. of grass weigh when dry -	45 dr.	392040	0=24502	8	0
The produce of the space, ditto -	576				
The weight lost by the produce of one acre in drying			=18957	8	0
64 dr. of grass afford of nutritive matter	5 dr.	54450	0= 3403	2	0
The produce of the space, ditto -	80				

LXXIII. *Elymus geniculatus.* Pendulous lyme-grass. Engl. Bot. 1586.

Pendulous sea-lyme grass. Nat. of England.

At the time of flowering, the produce from a sandy soil is —

Grass, 30 oz. The produce per acre -		326700	0=20418	12	0
80 dr. of grass weigh when dry -	32 dr.	130680	0= 8167	8	0
The produce of the space, ditto -	192				
The weight lost by the produce of one acre in drying -			12251	4	0
64 dr. of grass afford of nutritive matter	3·1 dr.	16590	3=1036	14	3
The produce of the space, ditto -	$24{\cdot}1\frac{1}{2}$				

LXXIV. *Bromus inermis.* Host. G. A. i. t. 9.

Awnless brome grass. Nat. of Germany. Introduced by Mr. Hunneman in 1794.

At the time the seed is ripe, the produce from a black sandy soil is —

Grass, 18 oz. The produce per acre -		196020	0=12251	4	0
80 dr. of grass weigh when dry -	35 dr.	85758	12= 5359	14	12
The produce of the space, ditto -	126				
The weight lost by the produce of one acre in drying -			6891	5	4
64 dr. of grass afford of nutritive matter	4·1 dr.	13016	15= 813	8	15
The produce of the space, ditto -	$19{\cdot}0\frac{3}{5}$				

The produce of the latter-math is —

Grass, 13 oz. The produce per acre -		141570	0=8848	2	0
54 dr. of grass afford of nutritive matter	1·1 dr.	2765	0= 172	13	0

LXXV. *Agrostis vulgaris.* Wither. Bot. ii. 132. Hud. A. capilaris; Dr. Smith, A. arenaria.

Fine bent grass. Nat. of Britain.

At the time the seed is ripe, the produce from a sandy soil is —

Grass, 14 oz. The produce per acre -		152460	0=9528	12	0
80 dr. of grass weigh when dry -	40 dr.	76230	0=4764	6	0
The produce of the space, ditto -	112				
The weight lost by the produce of one acre in drying -			4764	6	0
64 dr. of grass afford of nutritive matter	$1{\cdot}2\frac{3}{16}$	4019	15= 251	3	15
The produce of the space, ditto -	$5{\cdot}1\frac{1}{16}$				

This is one of the most common of the bents, likewise the earliest; in these respects it is superior to all others of the same family, but inferior to several of them in produce and the quantity of nutritive matter it affords. As the species of this family are generally rejected by the cultivator on account of the lateness of their flowering, and this circumstance, as has already been observed, does not always imply a proportional lateness of foliage, their comparative merits in this respect may be better seen by bringing them into one view, as to the value of their early foliage.

	The apparent difference of time.	Their nutritive powers.
Agrostis vulgaris	Middle of April	$1 \cdot 2\frac{3}{4}$
palustris	One week later	2·3
stolonifera	Two ditto	3·2
canina	Ditto, ditto	1·3
sticta	Ditto, ditto	1·2
nivea	Three weeks ditto	2
littoralis	Ditto, ditto	3
repens	Ditto, ditto	3
mexicana	Ditto, ditto	2
fascicularis	Ditto, ditto	2

LXXVI. *Agrostis palustris.* Wither. Bot. ii. p. 129. Var. 2, alba. Eng. Bot. 1189. A. alba.

Marsh bent-grass.

At the time of flowering, the produce from a bog earth is—

Grass, 15 oz. The produce per acre -	163350	6=10209	6	0
80 dr. of grass weigh when dry - 36 dr. / The produce of the space, ditto - 108	73507	8= 4594	3	8
The weight lost by the produce of one acre in drying -		5615	2	8
64 dr. of grass afford of nutritive matter 2·3 dr. / The produce of the space, ditto - $10 \cdot 1\frac{1}{4}$	7018	15= 438	10	15

At the time the seed is ripe, the produce is —

Grass, 20 oz. The produce per acre -	217800	0=13612	8	0
80 dr. of grass weigh when dry - 32 dr. / The produce of the space, ditto - 128	87120	0= 5445	0	0
The weight lost by the produce of one acre in drying -		8167	8	0
64 dr. of grass afford of nutritive matter 2·3 dr. / The produce of the space, ditto - 13·3	9358	9= 584	14	9
The weight of nutritive matter which is lost by taking the crop at the time of flowering, being one-fourth part of its value - - - - - -		146	3	10

The proportional value of grass in each crop is equal.

LXXVII. *Panicum dactylon.* Engl. Bot. 850. Host. G. A. ii. t. 18.

Creeping Panic grass. Nat. of Britain.

At the time of flowering, the produce from a sandy loam, with manure, is—

		oz.	or lbs. per acre.		
Grass, 46 oz. The produce per acre -		500940	0=31308	12	0
80 dr. of grass weigh when dry -	36 dr.	225423	0=14088	15	0
The produce of the space, ditto -	331·0⅘				
The weight lost by the produce of one acre in drying -			17219	13	0
64 dr. of grass afford of nutritive matter	2 dr.	15654	6= 9783	6	0
The produce of the space, ditto -	23				

LXXVIII. *Agrostis stolonifera.* Engl. Bot. 1532. Wither. Bot. ii. 181. (Fiorin, Dr. Richardson.)

Creeping bent. Nat. of Britain.

At the time of flowering, the produce from a bog soil is—

Grass, 26 oz. The produce per acre -		283140	0=17696	4	0
80 dr. of grass weigh when dry -	35 dr.	123873	12= 7742	1	12
The produce of the space, ditto -	182				
The weight lost by the produce of one acre - -			9732	15	0
64 dr. of grass afford of nutritive matter	3·2dr	15484	3= 967	12	0
The produce of the space, ditto -	22·3				

At the time the seed is ripe, the produce is—

Grass, 28 oz. The produce per acre -		304920	0=19057	8	0
80 dr. of grass weigh when dry -	36 dr.	137214	0= 8575	14	0
The produce of the space, ditto -	201·2⅗				
The weight lost by the produce of one acre in drying -			10481	10	0
64 dr. of grass afford of nutritive matter	3·2 dr.	16675	0=1042	3	5
The produce of the space, ditto -	24·2				
The weight of nutritive matter which is lost by taking the crop at the time of flowering, being nearly one-fourteenth of its value - - - - - -			74	7	2

LXXIX. *Agrostis stolonifera.* Var. angustifolia.

Creeping bent, with narrow leaves. Nat. of Britain.

At the time the seed is ripe, the produce from a bog soil is—

		oz.	or lbs. per acre.		
Grass, 26 oz. The produce per acre -		261360	0=16335	0	0
80 dr. of grass weigh when dry - 36 dr. The produce of the space, ditto - 172·3$\frac{1}{5}$		117612	0= 7350	12	0
The weight lost by the produce of one acre in drying -			8984	4	0
64 dr. of grass afford of nutritive matter 3 dr. The produce of the space, ditto - 18		12251	4= 765	11	4
The weight of nutritive matter afforded by the produce of one acre of the *Agrostis stolonifera* exceeding that of the variety in proportion, as 6 to 8 - -			276	8	1

The above details will assist the farmer in deciding on the comparative value of this grass. From a careful examination it will doubtless appear to possess merits well worthy of attention, though perhaps not so great as has been supposed, if the natural place of its growth and habits be impartially taken into the account. From the couchant nature of this grass, it is denominated couch-grass by practical men; and from the length of time that it retains the vital power, after being taken out of the soil, is called squitch, quick, full of life, &c.

LXXX. *Agrostis canina.* Engl. Bot. 1856. Brown-bent. Nat. of Britain.

At the time of flowering, the produce from a brown sandy loam is—

	oz.			
Grass, 9 oz. The produce per acre -	98010	0=6125	10	0
80 dr. of grass weigh when dry - 34 dr. The produce of the space, ditto - 63$\frac{1}{4}$	43013	0=2688	5	0
The weight lost by the produce of one acre in drying -		3437	5	0
64 dr. of grass afford of nutritive matter 2·2 dr. The produce of the space, ditto - 52·1$\frac{1}{2}$	3828	8= 239	4	8

LXXXI. *Agrostis canina.* Var. muticæ. Awnless brown bent. Nat. of Britain.

At the time the seed is ripe, the produce from a sandy soil is—

	oz.			
Grass, 21 oz. The produce per acre - -	228690	0= 14293	2	0
80 dr. of grass weigh when dry - 24 dr. The produce of the space, ditto - 100·3$\frac{1}{5}$	68607	0= 4287	15	0
The weight lost by the produce of one acre in drying -		10005	3	0
64 dr. of grass afford of nutritive matter 1·3 dr. The produce of the space, ditto - 9·0$\frac{3}{4}$	6253	3= 390	13	3
The weight of nutritive matter which the produce of one acre of the awnless variety exceeds that of the last-mentioned species - - - - - -		151	8	11

LXXXII. *Agrostis stricta.* Curt. A. rubra.

Upright bent-grass. Nat. of Britain.

At the time the seed is ripe, the produce from a bog soil is—

		oz.		or lbs. per acre.		
Grass, 11 oz. The produce per acre -		119790	0=	7486	14	0
80 dr. of grass weigh when dry -	29 dr.	43423	14=	2713	15	0
The produce of the space, ditto -	$63\frac{4}{5}$					
The weight lost by the produce of one acre in drying -				4772	15	0
64 dr. of grass afford of nutritive matter 1·2 dr.		2807	9=	175	7	5
The produce of the space, ditto -	$4{\cdot}0\frac{5}{10}$					

LXXXIII. *Agrostis nivea.*

Snowy bent-grass. Nat. of Britain.

At the time the seed is ripe, the produce from a sandy soil is--

Grass, 7 oz. The produce per acre -		76230	0=	4764	6	0
80 dr. of grass weigh when dry -	22 dr.	20963	4=	1310	3	0
The produce of the space, ditto -	$30{\cdot}3\frac{1}{5}$					
The weight lost by the produce of one acre in drying -				3454	3	0
64 dr. of grass afford of nutritive matter 2 dr.		2382	3=	148	14	3
The produce of the space, ditto -	$3\frac{1}{2}$					

LXXXIV. *Agrostis fascicularis.* Huds. Var. canina. Curt.

Tufted-leaved bent. Nat. of Britain.

At the time of flowering, the produce from a light sandy soil is—

Grass, 4 oz. The produce per acre -		43560	0=	2722	8	0
80 dr. of grass weigh when dry -	20 dr.	10890	0=	680	10	0
The produce of the space, ditto -	16					
The weight lost by the produce of one acre in drying -				2041	14	0
64 dr. of grass afford of nutritive matter 2 dr.		1361	4=	85	1	4
The produce of the space, ditto -	2					

LXXXV. *Festuca pinnata.* Bromus pinnatus. Engl. Bot. 730.

Spiked fescue. Nat. of Britain.

At the time the seed is ripe, the produce from a light sandy soil, with manure, is—

Grass, 30 oz. The produce per acre -		326700	0=	20418	12	0
80 dr. of grass weigh when dry -	32 dr.	130680	0=	8167	8	0
The produce of the space, ditto -	192					
The weight lost by the produce of one acre in drying -				12251	4	0
64 dr. of grass afford of nutritive matter 1·1 dr.		6380	13=	398	12	13
The produce of the space, ditto -	$9{\cdot}1\frac{2}{4}$					

LXXXVI. *Panicum viride,* Curt. Lond. Engl. Bot. 875.
Green panic grass. Nat. of Britain.

At the time the seed is ripe, the produce from a light sandy soil is—

		oz.		or lbs. per acre.		
Grass, 8 oz. The produce per acre -		87120	0=	5445	0	0
80 dr. of grass weigh when dry -	32 dr					
The produce of the space, ditto -	$51\frac{1}{5}$	·34848	0=	2178	0	0
The weight lost by the produce of one acre in drying -				3267	0	0
64 dr. of grass afford of nutritive matter	1·2 dr.					
The produce of the space, ditto -	3	2041	14=	127	9	14

LXXXVII. *Panicum sanguinale.* Curt. Lond. Engl. Bot. 849.

Blood-coloured panic grass. Nat. of Brit.

At the time the seed is ripe, the produce from a sandy soil is—

Grass, 10 oz. The produce per acre -	108900	0=	6806	4	0
64 dr. of grass afford of nutritive matter $1{\cdot}0\frac{2}{16}$	1914	4=	119	10	4

This and the preceding species are strictly annual, and from the results of this trial, their nutritive powers appear to be very inconsiderable. The seed of this species, Mr. Schreber describes (in Beschreibung der Graser) as the manna grass. In Poland, Lithuania, &c. it is collected in great abundance; when, after being thoroughly separated from the husks, it is fit for use. When boiled with milk or wine, it forms an extremely palatable food; and is most commonly made use of whole, in the manner of sago, to which it is in general preferred.

LXXXVIII. *Agrostis lobata.* Curtis, lobata et arenaria.
Lobed bent-grass.

At the time of flowering, the produce from a sandy soil is—

Grass, 10 oz. The produce per acre -		108900	=	6806	4	0
80 dr. of grass weigh when dry -	40 dr.					
The produce of the space, ditto -	80	54450	0=	3403	2	0
The weight lost by the produce of one acre in drying -				3403	2	0
64 dr. of grass afford of nutritive matter	3 dr.					
The produce of the space, ditto -	7·2	5104	11=	319	0	11

LXXXIX. *Agrostis repens.* Wither. Bot. A. nigra. Creeping-rooted bent, black bent. Nat. of Britain.

At the time of flowering, the produce from a clayey loam is—

		oz.		or lbs. per acre.		
Grass, 9 oz. The produce per acre -		98010	0=	6125	10	0
80 dr. of grass weigh when dry -	35 dr.	42879	6=	2679	15	6
The produce of the space, ditto -	63					
The weight lost by the produce of one acre in drying -				3445	10	10
64 dr. of grass afford of nutritive matter	3 dr.	4594	3=	287	2	8
The produce of the space, ditto -	6·3					

XC. *Agrostis mexicana.* Hort. Kew. i. p. 150. Mexican bent-grass. Nat. of S. America. Introduced 1780, by M. G. Alexander.

At the time of flowering, the produce from a black sandy soil is—

Grass, 28 oz. The produce per acre -		304920	0=	19057	8	0
80 dr. of grass weigh when dry -	28 dr.	106722	0=	6670	2	0
The produce of the space, ditto -	156·3$\frac{1}{5}$					
The weight lost by the produce of one acre in drying -				12387	6	0
64 dr. of grass afford of nutritive matter	2 dr.	9528	12=	595	8	12
The produce of the space, ditto -	14					

XCI. *Stipa pennata.* Engl. Bot. 1356. Long-awned feather grass. Nat. of Britain.

At the time of flowering, the produce from a heath soil is—

Grass, 14 oz. The produce per acre -		152460	0=	9528	12	0
80 dr. of grass weigh when dry -	29 dr.	55266	12=	3454	2	12
The produce of the space, ditto -	81$\frac{1}{5}$					
The weight lost by the produce of one acre in drying -				6074	9	4
64 dr. of grass afford of nutritive matter	1·3 dr.	6551	0=	409	7	0
The produce of the space, ditto -	9·2$\frac{1}{2}$					

XCII. *Triticum repens.* Engl. Bot. 909. Creeping-rooted wheat-grass. Nat. of Britain.

At the time of flowering, the produce from a light clayey loam is—

		oz.		or lbs. per acre.		
Grass, 18 oz. The produce per acre -		196020	0	=12251	4	0
80 dr. of grass weigh when dry -	32 dr.	78408	0	= 4900	8	0
The produce of the space, ditto -	115⅕					
The weight lost by the produce of one acre in drying -				7350	12	0
64 dr. of grass afford of nutritive matter	2 dr.	6125	10	= 382	13	10
The produce of the space, ditto -	9					

64 dr. of the roots afford of nutritive matter 5·3 dr. The proportional value of the roots, is therefore to that of the grass, as 23 to 8.

XCIII. *Alopecurus agrestis.* Engl. Bot. 848. A. myosuroides.

Slender fox-tail grass. Nat. of Britain. Curt. Lond.

At the time of flowering, the produce from a light sandy loam is—

Grass, 12 oz. The produce per acre -		130680	0	= 8167	8	0
80 dr. of grass weigh when dry -	31 dr.	50638	8	= 3164	14	8
The produce of the space, ditto -	74·1⅗					
64 dr. of grass afford of nutritive matter	1·3 dr.	3573	4	= 223	5	4
The produce of the space, ditto -	5·1					

XCIV. *Bromus asper.* Engl. Bot. 1172. Curt. Lond. Bromus hirsutus. Huds. Bromus ramosus. B. sylvaticus, volger. B. altissimus.

Hairy-stalked brome-grass. Nat. of Britain.

At the time of flowering, the produce from a light sandy soil is—

Grass, 20 oz. The produce per acre -		217800	0	=13612	8	0
80 dr. of grass weigh when dry -	24 dr.	65340	0	= 4083	12	0
The produce of the space, ditto -	96					
The weight lost by the produce of one acre in drying -				9528	12	0
64 dr. of grass afford of nutritive matter	2 dr.	6806	4	= 425	6	4
The produce of the space, ditto -	10					

XCV. *Phalaris Canariensis.* Engl. Bot. 1310.

Common canary-grass. Nat. of Britain.

At the time of flowering, the produce from a clayey loam is—

Grass, 80 oz. The produce per acre -		871200	0	=54450	0	0
80 dr. of grass weigh when dry -	26 dr.	283177	8	=17697	9	8
The produce of the space, ditto -	416					
The produce in weight lost by drying -		-		36752	6	6
64 dr. of grass afford of nutritive matter	1·2 dr.	20418	12	= 1876	2	12
The produce of the space, ditto -	30					

XCVI. *Melica cærulea.* Curt. Lond. Engl. Bot. 750. Purple melic grass. Nat. of Britain.

At the time of flowering, the produce from a light sandy soil is —

		oz.	or lbs. per acre.		
Grass, 11 oz. The produce per acre -		119790	0=7486	14	0
85 dr. of grass weigh when dry -	30 dr.	44921	4=2807	9	4
The produce of the space, ditto -	66				
The weight lost by the produce of one acre in drying -		-	4679	4	2
64 dr. of grass afford of nutritive matter	1·2 dr.	2756	8= 172	4	8
The produce of the space, ditto -	$2{\cdot}0\frac{3}{4}$				

XCVII. *Dactylis cynosuroides.* Linn. fil. fasci. 1. p. 17. American cock's-foot grass. Nat. of N. America.

At the time of flowering, the produce from a clayey loam is —

Grass, 102 oz. The produce per acre -		111780	0=69423	1	0
80 dr. of grass weigh when dry -	48 dr.	666468	0=41654	4	0
The produce of the space, ditto -	$979\frac{1}{5}$				
The weight lost by the produce of one acre in drying -			27769	8	0
64 dr. of grass afford of nutritive matter	1·3dr.	30372	0= 1898	4	0
The produce of the space, ditto -	$44{\cdot}2\frac{2}{4}$				

Of the Time in which different Grasses produce Flowers and Seeds.

To decide positively the exact period or season when a grass always comes into flower, and perfects its seed, will be found impracticable; for a variety of circumstances interfere. Each species seems to possess a peculiar life, in which various periods may be distinctly marked, according to the varieties of its age, of the seasons, soils, exposures, and mode of culture.

The following Table, which shows the time of flowering, and the time of ripening the seed of those grasses growing at Woburn which are mentioned in the Experiments, must therefore only be considered as serving for a test of comparison, for the different grasses growing under the same circumstances.

Names.	Time of flowering.	Time of ripening the seed.
Anthoxanthum odoratum - -	April 29	June 21
Holcus odoratus - - - -	April 29	June 25
Cynosurus cæruleus - - -	April 30	June 20
Alopecurus pratensis - - -	May 20	June 24
Alopecurus alpinus - - -	May 20	June 24
Poa alpina - - - -	May 30	June 30
Poa pratensis - - - -	May 30	July 14
Poa cærulea - - - -	May 30	July 14
Avena pubescens - - -	June 13	July 8
Festuca hordiformis - - -	June 13	July 10
Poa trivialis - - - -	June 13	July 10
Festuca glauca - - - -	June 13	July 10
Festuca glabra - - - -	June 16	July 10
Festuca rubra - - - -	June 20	July 10
Festuca ovina - - - -	June 24	July 10
Briza media - - - -	June 24	July 10
Dactylis glomerata - - -	June 24	July 14
Bromus tectorum - - -	June 24	July 16
Festuca cambrica - - -	June 28	July 16
Bromus diandrus - - -	June 28	July 16
Poa angustifolia - - -	June 28	July 16
Avena elatior - - - -	June 28	July 16
Poa elatior - - - -	June 28	July 16
Festuca duriuscula - - -	July 1	July 20
Milium effusum - - - -	July 1	July 20
Festuca pratensis - - -	July 1	July 20
Lolium perenne - - - -	July 1	July 20
Cynosurus cristatus - - -	July 6	July 28
Avena pratensis - - -	July 6	July 20
Bromus multiflorus - - -	July 6	July 28
Festuca loliacea - - - -	July 1	July 28
Poa cristata - - - -	July 4	July 28
Festuca myurus - - -	July 6	July 28
Aira flexuosa - - - -	July 6	July 28
Hordeum bulbosum - - -	July 10	July 28
Festuca calamaria - - -	July 10	July 28
Bromus littoreus - - -	July 12	Aug. 6
Festuca elatior - - -	July 12	Aug. 6
Nardus stricta - - - -	July 12	Aug. 6
Triticum (species of) - - -	July 12	Aug. 10
Festuca fluitans - - - -	July 14	Aug. 12
Festuca dumetorum - - -	July 14	July 20
Holcus lanatus - - - -	July 14	July 26
Poa fertilis - - - -	July 14	July 28
Arundo colorata - - - -	July 16	July 28
Poa (species of) - - - -	July 16	July 30
Cynosurus erucæformis - -	July 16	July 30
Phleum nodusum - - -	July 16	July 30
Phleum pratense - - -	July 16	July 30
Elymus arenarius - - -	July 16	July 30

Names.	Time of flowering.	Time of ripening the seed.
Elymus geniculatus - - -	July 18	July 30
Trifolium pratense - - -	July 18	July 30
Trifolium macrorhizum - - -	July 18	July 30
Sanguisorba canadensis - - -	July 18	July 30
Bunias orientalis - - -	July 18	July 30
Medicago sativa - - -	July 18	Aug. 6
Hedysarum onobrychis - - -	July 18	Aug. 8
Hordeum pratense - - -	July 20	Aug. 8
Poa compressa - - -	July 20	Aug. 8
Poa aquatica - - - -	July 20	Aug. 8
Bromus cristatus - - -	July 24	Aug. 10
Elymus sibiricus - - -	July 24	Aug. 10
Aira cæspitosa - - - -	July 24	Aug. 10
Avena flavescens - - -	July 24	Aug. 15
Bromus sterilis - - - -	July 24	Aug. 20
Holcus mollis - - - -	July 24	Aug. 20
Bromus inermis - - - -	July 24	Aug. 20
Agrostis vulgaris - - -	July 24	Aug. 20
Agrostis palustris - - -	July 28	Aug. 28
Panicum dactylon - - -	July 28	Aug. 28
Agrostis stolonifera - - -	July 28	Aug. 28
Agrostis stolonifera (var.) - -	July 28	Aug. 28
Agrostis canina - - - -	July 28	Aug. 28
Agrostis stricta - - - -	July 28	Aug. 30
Festuca pennata - - - -	July 28	Aug. 30
Panicum viride - - - -	Aug. 2	Aug. 15
Panicum sanguinale - - -	Aug. 6	Aug. 20
Agrostis lobata - - - -	Aug. 6	Aug. 20
Agrostis repens - - - -	Aug. 8	Aug. 25
Agrostis fascicularis - - -	Aug. 10	Aug. 30
Agrostis nivea - - - -	Aug. 10	Aug. 30
Triticum repens - - - -	Aug. 10	Aug. 30
Alopecurus agrestis - - -	Aug. 10	Sept. 8
Bromus asper - - - -	Aug. 10	Sept. 10
Agrostis mexicana - - -	Aug. 15	Sept. 25
Stipa pennata - - - -	Aug. 15	Sept. 25
Melica cærulea - - - -	Aug. 20	Sept. 30
Phalaris canariensis - - -	Aug. 30	Sept. 30
Dactylis cynosuroides* - -	Aug. 30	Oct. 20

* In the experiments made on the quantity of nutritive matter in the grasses cut at the time the seed was ripe, the seeds were always separated, and the calculations for nutritive matter, as is evident from the details, made for grass and not hay.

Of the different Soils referred to in the Appendix.

In books on agriculture and gardening much uncertainty and confusion arise from the want of regular definitions of the various soils, to distinguish them specifically by the names generally used: thus the term "bog-earth" is almost constantly confounded with peat-moss, and heath soil; also the terms "light loam," "heavy soil," &c. are given without distinguishing whether that be "light" from sand, or this "heavy" from clay. In minute experiments, it is doubtless of consequence to be as explicit as possible in those particulars. The following short descriptions of such soils as are mentioned in the details of the experiment are here given for the above purpose:—

1st. By "loam" is meant any of the earths combined with decayed animal or vegetable matter.

2d. "Clayey-loam," when the greatest proportion is clay.

3d. "Sandy-loam," when the greatest proportion is sand.

4th. "Brown-loam," when the greatest proportion consists of decayed vegetable matter.

5th. "Rich black loam," when sand, clay, animal and vegetable matters are combined in unequal proportions, the clay greatly divided, being in the least proportion, and the sand and vegetable matter in the greatest.

The terms "light sandy soil," "light brown loam," &c. are varieties of the above, as expressed.

Observations on the Chemical Composition of the Nutritive Matter afforded by the Grasses in their different States.—By Sir H. Davy.

I have made experiments on most of the soluble products supposed to contain the nutritive matter of the grasses, obtained by Mr. Sinclair; and I have analysed a few of them. Minute details on this subject would

be little interesting to the agriculturist, and would occupy a considerable space; I shall therefore content myself with mentioning some particular facts, and some general conclusions, which may tend to elucidate the inquiry respecting the fitness of the different grasses for permanent pasture, or for alternation as green crops with grain.

The only substances which I have detected in the soluble matters procured from the grasses are mucilage, sugar, bitter extract, a substance analogous to albumen, and different saline matters. Some of the products from the after-math crops gave feeble indications of the tanning principle.

The order in which these are nutritive has been mentioned in the First Lecture: the albumen, sugar, and mucilage, probably, when cattle feed on grass or hay, are for the most part retained in the body of the animal; and the bitter principle, extract, saline matter, and tannin, when any exist, probably for the most part are voided in the excrement with the woody fibre. The extractive matter obtained by boiling the fresh dung of cows is extremely similar in chemical characters to that existing in the soluble products from the grasses. And some extract, obtained by Mr. Sinclair from the dung of sheep and of deer, which had been feeding upon the Lolium perenne, Dactylis glomerata, and Trifolium repens, had qualities so analogous to those of the extractive matters obtained from the leaves of the grasses, that they might be mistaken for each other. The extract of the dung, after being kept for some weeks, had still the odour of hay. Suspecting that some undigested grass might have remained in the dung, which might have furnished mucilage and sugar as well as bitter extract, I examined the soluble matter very carefully for these substances. It did not yield an atom of sugar, and scarcely a sensible quantity of mucilage.

Mr. Sinclair, in comparing the quantities of soluble matter afforded by the mixed leaves of the Lolium perenne, Dactylis glomerata, and Trifolium repens, and

that obtained from the dung of cattle fed upon them, found their relative proportions as 50 to 13.

It appears probable from these facts that the bitter extract, though soluble in a large quantity of water, is very little nutritive; but probably it serves the purpose of preventing, to a certain extent, the fermentation of the other vegetable matters, or in modifying or assisting the function of digestion, and may thus be of considerable use in forming a constituent part of the food of cattle. A small quantity of bitter extract and saline matter is probably all that is needed; and beyond this quantity the soluble matters must be more nutritive in proportion as they contain more albumen, sugar, and mucilage, and less nutritive in proportion as they contain other substances.

In comparing the composition of the soluble products afforded by different crops from the same grass, I found, in all the trials I made, the largest quantity of truly nutritive matter in the crop cut when the seed was ripe, and least bitter extract and saline matter; most extract and saline matter in the autumnal crop; and most saccharine matter, in proportion to the other ingredients, in the crop cut at the time of flowering. I shall give one instance:—

100 parts of the soluble matter obtained from the Dactylis glomerata, cut in flower, afforded—

of sugar - - -	18 parts.
of mucilage - - -	67
of coloured extract, and saline matters with some matter rendered insoluble by evaporation - - -	15

100 parts of the soluble matter from the seed crop afforded—

of sugar - - -	9 parts.
of mucilage - - -	85
of extract, insoluble and saline matters -	6

100 parts of soluble matter from the after-math crop give—

of sugar - - -	11 parts.
of mucilage - - -	59
of extract, insoluble and saline matters -	30

The greater proportion of leaves in the spring, and particularly in the late autumnal crop, accounts for the difference in the quantity of extract; and the inferiority of the comparative quantity of sugar in the summer crop probably depends upon the agency of light, which tends always in plants to convert saccharine matter into mucilage or starch.

Amongst the soluble matters afforded by the different grasses, that of the Elymus arenarius was remarkable for the quantity of saccharine matter it contained, amounting to more than one-third of its weight. The soluble matters from the different species of Festuca, in general afforded more bitter extractive matter than those from the different species of Poa. The nutritive matter from the seed crop of the Poa compressa was almost pure mucilage. The soluble matter of the seed crop of Phleum pratense, or meadow cat's-tail, afforded more sugar than any of the Poa or Festuca species.

The soluble parts of the seed crop of the Holcus mollis and Holcus lanatus contained no bitter extract, and consisted entirely of mucilage and sugar. Those of the Holcus odoratus afforded bitter extract, and a peculiar substance having an acrid taste more soluble in alcohol than in water. All the soluble extracts of those grasses that are most liked by cattle have either a saline or subacid taste; that of the Holcus lanatus, is similar in taste to gum arabic. Probably the Holcus lanatus, which is so common a grass in meadows, might be made palatable to cattle by being sprinkled over with salt.

I have found no differences in the nutritive produce of the crops of the different grasses cut at the same season, which would render it possible to establish a scale of their nutritive powers: but probably the soluble matters of the after-math crop are always from one-sixth to one-third less nutritive than those from the flower or seed crop. In the after-math the extractive and saline matters are certainly usually in excess; but the after-math hay mixed with summer hay, particularly that in which the fox-tail and soft grasses are abundant, would produce an excellent food.

Of the clovers, the soluble matter from the Dutch clover contains most mucilage, and most matter analagous to albumen: all the clovers contain more bitter extract and saline matter than the common proper grasses. When pure clover is to be mixed as fodder, it should be with summer hay rather than after-math hay.

[APPENDIX II.

*Letter of Sir H. Davy to B. H. Macarthy, Esq., on the Cultivation of Bogs in Ireland.**]

SIR,

As the Commissioners for considering the practicability of draining the bogs of Ireland have done me the honour of requesting my opinion on the important national object to which their attention is directed, I shall, without apology, beg leave to communicate to them, through your means, such observations as I have been able to make on the subject.

Bogs, in general, are known to consist of inert vegetable matter, covered more or less with unproductive vegetables, and containing a large quantity of stagnant water. There are two causes why they are unfitted for cultivation. One is the existence of stagnant moisture, the other is the excess of inert vegetable matter. There is but one mode of removing the stagnant water, which belongs to the practical engineer, and that is, by draining; the different modes of effecting this have been so ably discussed in the Reports before the Commissioners,

* [This letter on a very important national object, was inserted in the Parliamentary Reports of the Commissioners for improving the Bogs in Ireland.]

and which they were pleased to request me to peruse, that it would be presumptuous in me to offer any observations upon this part of the inquiry.

The mode of removing the excess of inert vegetable matter, and of rendering it useful, is a subject which more immediately comes within the province of Chemistry; and on this I shall venture to offer some suggestions.

Bogs differ very much in their composition. In general, 100 parts of dry peat contain from 60 to 99 parts of matter, destructible by fire, and the residuum consists of earths, usually of the same kind as the substratum of clay, marle, gravel, or rock, on which they are found, and oxide of iron. Burning furnishes a simple mode of destroying the inert vegetable matter, and where the part contains much earthy matter, tends to supply that which is necessary in every fertile soil, a due proportion of the earths. From the analyses of Mr. Griffiths of several specimens of a particular bog, it appears, however, that this practice will not be universally applicable, for he found 1440 parts of several specimens of peat, affording only from 12 to 50 parts of ashes; the proportions being greatest in the lower strata. In cases where lime can be applied to the surface of bogs, there can be no doubt of its beneficial efficacy. If used in its state of quicklime, it not only destroys excess of vegetable matter, but forms a compost extremely favourable to the vegetation of esculent plants.* The peat hills of Derbyshire have many of them been rapidly brought into cultivation, by merely draining, and scattering lime over the surface; and treated in this way,

* [That lime has an excellent effect, applied in the manner stated above, is certain; but how it operates in producing the effect, is a subject for further inquiry. Vide Vol. VII. p. 192.]

they admit, I believe, of being ploughed up the second year, and sown with oats, or planted with potatoes. Any kind of soil will improve peat; sand, clay, or marle, must be all beneficial, because a great object is to increase the quantity of earth in proportion to the vegetable matter. If a peat is of a black colour, soft consistence, and contains living vegetables at the surface, it will probably be easy of improvement, by liming, or the application of the earths. If it is an inert red peat, containing little decomposing vegetable matter, and having only moss at its surface, there is reason to conceive that attempts at improvement should be preceded by burning the surface.

To render bogs arable land, capable of bearing white crops, there must be a certain quantity of earth added to the vegetable matter, or a certain quantity of vegetable matter destroyed, but it appears probable that many bogs may be made into good pasture, by draining and sowing indigenous or foreign grasses, particularly if irrigation can be employed. In England this practice has been particularly successful. At Priestly, near Woburn, and at Castle Aere, there are meadows which have rapidly been reclaimed from bog, and which produce luxuriant and excellent crops of grass in consequence of irrigation.

The Commissioners will appreciate the value and importance of my excellent friend, Dr. Richardson's ideas on the improvement of bogs, by cultivating on them the indigenous Irish grasses.

From a comparison of the able Reports of Messrs. Edgworth and Griffith, it appears evident, that very different plans of cultivation must be adopted in different cases. The chemical composition of bogs, and the ashes they afford, differ exceedingly, as I have found in va-

rious experiments upon specimens of peat from different districts.

The peat of the chalk counties of England contains much gypsum; but I have found very little in any specimens from Ireland or Scotland: and, in general, these parts contain very little saline matter.

There are peculiar advantages, which will strike every one in judging of the practicability of improving most of the great bogs in Ireland, the quantity of limestone, and limestone gravel, in the neighbouring districts, and the marle or clay which, in so many cases, forms the substratum of the bog. If the draining can be easily effected, if the upper stratum can, by mechanical means, be freed from its excess of water, there is no doubt that its cultivation might be rapidly effected.

A few experiments upon the modes of improving those bogs most unlike each other, would be, perhaps, the best preliminary step towards laying the foundations for the great national undertaking. This would probably lead to particular plans for each particular district, which would be directed by a minute knowledge of the local circumstances, and by chemical analysis, pointing out the particular nature of the peat.

A soil, covered with peat, is a soil covered not only with fuel, but likewise with manure. It is the excess of manure only which is detrimental; and it is much more easy to destroy it than to create it. To cultivate a bog is a much less difficult task than to improve a sand. If there is a proper level to admit of draining, the larger the scale of operation the less must the comparative expense be, because machinery may, for many purposes, take the place of manual labour; and the trials that have been already made by private individuals, and which are stated in the different Reports, prove not only

the feasibility of the general project, but afford strong grounds to believe that any capital expended upon it, after mature and well digested plans, would, in a very few years, afford a great and increasing interest, and would contribute to the wealth, prosperity, and population of the Island.

I have the honour to be, Sir,

Your most obedient Servant,

H. Davy.

[Of the large number of Lectures written by the author, during a period of nearly twelve years that he was professor of chemistry at the Royal Institution, comparatively few remain, and these evidently not a selection. Their preservation seems to have been accidental; he was careless of them, and after they had served the purpose for which they had been specially written, they were thown aside, and, it may be inferred, had not a second thought bestowed on them. Those which follow are given, not so much for the sake of exemplifying his manner of lecturing, in which respect however it is conceived they may not be uninteresting, as on account of what is believed to be their intrinsic excellence, and the interest belonging to them in relation to the time when they were delivered, and the circumstances associated with them. Not intended for publication, rapidly written, as they almost invariably were on the spur of the occasion, they are brought forward with the hope that they will be viewed as sketches, not as finished compositions, and that if critically examined they will be judged of accordingly. Between these examples of his lectures and the extracts from other lectures which will follow, it has been thought right to insert a short paper intitled "Parallels between Art and Science," which was published anonymously, in 1807, in a periodical called "The Director," said to have been under the benevolent guidance of his friend Sir Thomas Barnard. Even if the editor had not been assured on good authority that it was written by the author, he could not doubt it, it bears so strongly the impress of his mind. It may be mentioned as a curious circumstance, that this is the only instance of anonymous writing that can be traced to his pen; and his only contribution to what can be considered periodical literature. He was too intent on original scientific research to be tempted either by fame or profit to give his aid, often solicited, to any of the distinguished Reviews of the day.]

INTRODUCTORY LECTURE FOR THE COURSES OF 1805.*

The love of knowledge and of intellectual power is a faculty belonging to the human mind in every state of society; and it is one by which it is most justly characterised—one the most worthy of being cultivated and extended.

Useful to the individual, and even necessary to his existence, its general effects upon the species are, in the highest degree, important and beneficial; and the improvements in the condition and in the happiness of mankind, appear, in all instances, to have preserved an uniform pace with the progress of the inventions of the arts, and the advancement in the sciences.

This truth scarcely requires any demonstration. To prove it, there is no necessity for recurring to any refined arguments: the mere comparison of the rude, and of the cultivated state of society, must carry conviction to every unprejudiced understanding. In the dreams of a brilliant imagination, indeed, the uncivilized state of man may appear in high and vivid tints of happiness; and the fancy of an enthusiast may enable him to draw strong contrasts between nature and art unfavourable to

* [This is the earliest MS. Lecture of the author's which has been preserved. Both its application and its topics (the cultivation of the intellect and the advantages of knowledge) indicate that it was not designed solely as an introduction to his own Lectures, but to the courses of Lectures generally which were to be delivered during the Session at the Royal Institution.]

the latter; between blue skies, verdant groves, murmuring streams, the scenery of a mountain country, and the smoke and dirt of towns, the noise and bustle of commerce, and the insipidity of productive plains; between the earth wildly and spontaneously producing food, and grounds made fertile only by human labour; between the vices, miseries, and dependence of man in society, and his simple virtues, his lofty pastoral manners, and his unsubdued freedom in the condition of nature.

Such romantic pictures, though they should be adorned with the highest colouring of genius, can, however, scarcely, in the slightest degree affect the opinion of sound and judicious reasoners. The details of past times, the narrations of travellers, or even a simple observation of the habits and propensities of the human mind, are sufficient to demonstrate that its highest enjoyments are connected with an active state of the understanding, and an exalted social intercourse,—are sufficient to demonstrate, that the being whose pleasures are only produced by the gratification of his common wants, and whose wants are constantly limited by the poverty of nature, can never be justly opposed to the man whose delights are, in a great measure, conformable to his wishes; whose intellectual gratifications are even more numerous than his appetites, and whose mind is the *master* of his body, and not its *slave.*

Many speculative men, whose minds have been awake to the advantages of improvement, have, nevertheless, conceived that, in all cases, there must be certain limits to the progress of civilization,—have conceived that the sciences and the arts, however beneficial in their first effects, must finally tend to enfeeble the character, and to promote the increase of luxury. Such persons have

generally founded their opinions upon incorrect views of the history of ancient nations; and, haunted by ideas of their rapid elevation and downfall, have believed that the same powers operate in modern times, and that the germs of the ruin of states exist in those very causes which have produced their greatness. That power, riches, and leisure, are essential to a great extension of philosophy and literature, and that they are likewise often the causes of vice and depravation, cannot, indeed, be denied; but a few facts, derived even from the history of the empires of antiquity, will distinctly show, that the influences of the arts and sciences, in great and wealthy states, tend rather to depress than to promote common luxury; and that those periods the most distinguished by elevation of moral character, by the social virtues, and by the higher feelings of the soul, were likewise the periods in which philosophy and letters were most cultivated, and in which the fine arts were ardently pursued. The most happy period of Grecian civilization is that between the first Persian and the second Peloponnesian war. It was at the beginning of this period that literature and science made their first progress in Greece; and, at the time that they were studied with the greatest ardour, the patriotic spirit and the heroical virtue of the people were revealed in their full splendour. It was at the beginning of this period when Anaxagoras was instructing the youth of Athens in speculative philosophy; when Hippocrates was laying the foundations of medical science; when Democritus was pursuing the paths of experimental inquiry. It was at the same time that the minds of the inhabitants of Attica were kindling with the poetic feeling raised by the immortal genius of Homer. It was at the same time that they prosecuted their most active war of

liberty against the Persians; that Miltiades and Themistocles led on their troops to conquest. It was at the same time that Leonidas and his 300 Spartans fell at Thermopylæ, martyrs in the cause of freedom, and glorying that they were permitted to die for their country. It was towards the close of this period that sculpture, painting, and the arts of life, flourished in full vigour. It was at this time that the chisel of Phidias raised out of the rude marble forms of majesty and grace. It was at this time that the same dramatic poet, Sophocles—whose immortal compositions will ever continue as models of excellence—appeared as a warrior and conqueror at the head of armies; and that the same philosopher, who was called the wisest of men, endured all the hardships that the life of a common soldier can offer. And, perhaps, the character of the age can scarcely be better delineated than in one of the incidents in which he was the actor. Alcibiades, his disciple, was wounded in the battle of Delium. Socrates carried him on his shoulders, defended him, and dared, at the same moment, to expose his life for his friend and his country.

Traits of a very different character marked the later periods of the republics of Greece; and, at the era when they were about to resign their liberties to the power of Macedon, the sciences and arts no longer flourished in their ancient seats, but had passed into the country of the conqueror. At this time Aristotle was obliged to fly from Athens; and a law was passed to prevent any teacher of philosophy from opening a school in that city, which had before been the theatre of her glory. Luxury and sensuality only occupied the minds of the people; and no persons were distinguished by public approbation except such as gave great entertainments,

or such as possessed fortunes, which enabled them to gamble largely; and, as we are informed by Athenæus, the year before the invasion of Philip, the freedom of the city (an honour which before had been bestowed only upon potentates, warriors, and philosophers) was given to two young men, whose only merit was, that their father had been one of the best cooks in the commonwealth.

The same principles might be illustrated by examples from many other nations. Rome affords as many instances, and of precisely the same kind as Greece. And at a later period, the elevation, progress, and the decline of the power of the Arabians, depended upon similar causes. The only time at which this last people were truly great and happy, was at the time in which literature and science were patronised by Almansor and his successors, the caliphs of Bagdad. At the moment that the desire of intellectual improvement disappeared, the savage and sensual spirit of the religion of Mahomet carried its followers on to ruin, even amidst the triumphs of conquest; and the progress of the crescent, at first marked by victory and desolation, soon finished in ignorance and debility. All experience, all analogy, decidedly proves that, unless power and riches are employed for increasing the sources of mental gratification, and for keeping alive the activity of the soul, their tendency must be evil; and all the elder nations, who have fallen from greatness, have offered before their ruin similar characters: wealth without science, improving manufactures, or commerce; the few the conquerors of the many; and great cities peopled only with soldiers, with rich men, with parasites, and slaves.

The refinements of the useful or ornamental arts in modern times bear no relation to the luxuries of the

civilized nations of antiquity; and, as they are at present pursued, they are amongst the first causes of the general improvement of society; for they not only promote individual comfort, but they afford constant objects for employment: they preserve the love of invention; they promote emulation, and the desire of excellence, amongst the labourers in the same department; and they tend to unite the different classes of society by ties of usefulness, of mutual dependence, and of mutual advantage.

To the superficial observer, the attempt to extend the refinements of inventions beyond that state in which they are fitted for all the useful purposes of life, may appear wholly unnecessary; but it should be remembered, that, in aiming at perfection in a manufacture, the workman is constantly improving himself; and, in attempting to produce articles which are to sell at a high price, he makes a number much better than they would otherwise be, which are disposed of at a moderate rate.

A finely polished knife, for instance, which costs a guinea, may not have a better edge than one which sells for a shilling only; but the cutler who has produced the expensive knife, from his accurate acquaintance with his art, gained from habit and laborious operation, is able to make the common knife better, and at a lower rate. A thousand cases of the same kind might be adduced. The elegant models of the Etruscan vases, produced by the ingenuity of the late excellent Mr. Wedgewood, may be said to have no immediate application to common uses; but yet, in consequence of their invention, a spirit of imitation and emulation has operated upon every branch of the porcelain manufacture, and even the forms and composition of our common

pitchers and common flower-pots have, in consequence, been improved.

In certain departments of industry still greater advantages result from the constant attempts to attain the highest degrees of excellence. Examine agriculture. No person, who understands the luxuries of the table, will assert that a sheep, rendered enormously fat in rich pasture, or on turnips, is better, or a greater luxury, than one that has grazed on the aromatic herbage of the Welch mountains;—but in the attempt to produce this well-fed animal, which, perhaps, gains the prize at Smithfield, a number of others have been improved to a less extent, and rendered, in consequence, more adapted to common use. And the high price of well-fed cattle has awakened the feeling of emulation amongst farmers, in consequence of which the nature of the best breeds of cattle has been studied; the manner in which they can be most efficaciously nourished considered; and, from the extension of such inquiries, all the principles of farming have been more minutely investigated, and the art of cultivating land improved, and adorned with new discoveries. The principle is general: whenever manufactures, or any productions of art become articles of general consumption, the higher and more expensive refinements of them are absolutely necessary, not merely for their improvement, but likewise to prevent their decline.

All parts of the system of commerce are intimately connected. Honourably acquired wealth in such a country as that in which we have the happiness to live, —honourably acquired wealth, I say, produces credit, and from credit arises capital capable of an extent almost indefinite. Hence proceeds the division of labour; hence the invention of machinery; hence the circula-

tion of wealth and power from one extremity of the empire to the other; and communicating, like the vital blood flowing through the vessels, to every part health and strength. Hence all the productions of the globe are made subservient to the uses of man; and nature arises subdued by artificial means, not impoverished or deformed, but enriched, and rendered more beautiful.

The useful arts in modern times have attained an infinitely higher degree of perfection than in the most splendid eras of antiquity; and the improvements and extension of the sciences will admit of no parallel instances. That light of knowledge, which was only dimly perceived by the ancients, which was obscured by the clouds of error and of prejudice, has appeared to us in all its purity and brightness; and whilst Nature, and the order established by the Author of Nature, have been to a great extent developed, the science of man has not been neglected. The works which awaken the imagination and exalt the feelings have preserved all their effect upon the mind. By means of experiment a new creation, as it were, of facts has appeared —of facts as much superior to mere speculations as things can be to words. Letters, the great instruments of thought, have assisted science, and science has given new objects and new forms for adorning and extending literature. All the different branches of knowledge have assisted each other, and, like different instruments of music, the sounds of which combine in harmony, they have all co-operated, in enlightening the mind, in extending its enjoyments, and in exalting the state of social life.

Though so magnificent a structure has been raised in science rapidly, and as if by a kind of enchantment,

yet it is still unfinished, and new labours, and new efforts of ingenuity, are required both for ornamenting and extending it, and for preventing any of its parts from falling into decay. Knowledge is like a river, which, unless its springs are constantly supplied, soon becomes exhausted, and ceases to flow on, and to fertilize. The mind requires novelty even as a stimulus to exertion; and the philosopher who has made a discovery in natural science, or the author of a work of genius in art or in literature, is a benefactor, not only to the present generation, but likewise to future ages; for he gratifies that faculty of enjoyment which is pure and intellectual, and which must be more exalted as society becomes more improved.

Very few persons in the present day are disposed to reason against the advantages resulting from the higher refinements of science and philosophy, and the only argument that can be brought forward is one founded upon the doctrine of common utility. When a new fact, for instance, is ascertained in chemistry, or in electricity, the superficial observer is very apt to slight it, if it does not immediately admit of some application to the common wants of life. This, however, is very unfair; for all experience proves that the greatest and most important inventions which have arisen from scientific principles have never been ascertained till long after the principles themselves were developed; and so intimately connected are all the objects of human inquiry, and so much dependent upon the sensible properties of bodies, that it is scarcely possible that any great theoretical improvement can be made without being soon accompanied with practical advantages. A newly-discovered country ought not to be neglected, though it cannot be immediately brought into cultiva-

tion, because it does not immediately produce corn, and wine, and oil.

But, independently of these considerations, all truths in nature, all inventions by which they can be developed, are worthy of our study, for their own sake, rather than with any idea of profit or interest. Whatever can enlarge the views of the mind, raise new sentiments of intellectual pleasure, or make us acquainted with new properties and powers in the substances surrounding us, is in the highest degree worthy of the pursuit of a being whose noblest faculties are reason and the love of knowledge.

All the discoveries, all the works of human genius, are of great importance to the community; but that their full effects may be produced, it is necessary that the public mind be prepared to enjoy them, and to estimate their advantages. The general diffusion of letters and philosophy is necessary to the progress of the higher inventions of the mind; for unless the labours of men of ingenuity meet with public support and approbation, they can never be actively pursued, and must soon languish and die. All minds require hope to animate them to exertion, and the desire of glory is one of the most common to great and elevated understandings. The increase of general knowledge must uniformly produce the general patronage of letters and philosophy, and this is a most excellent and important end. Men of genius, in former times, have often languished in obscurity, not because their merits were neglected, but because they were not understood. This, however, can scarcely happen in the present day, in which all sources of useful information are laid open, and in which unparalleled exertions have been made in the higher classes of society to diffuse improvement, and to promote all

objects of inquiry which can benefit or enlighten the public. There are other uses, still greater uses, resulting from the communication of general and popular science. By means of it vulgar errors and common prejudices are constantly diminished. It offers new topics for conversation, and new interests in life. In solitude, it affords subjects for contemplation, and for an active exercise of the understanding, and in cities, it assists the cause of religion and morality, by preventing the increase of gross luxury and indulgence in vicious dissipation. Man is designed for an active being; and his spirit, ever restless, if not employed upon worthy and dignified objects, will often rather engage in mean and low pursuits than suffer the tedious and listless feelings connected with indolence; and knowledge is no less necessary in strengthening the mind, than in preserving the purity of the affections and the heart.

Some few arguments are now and then brought forward against the efficacy of popular instruction. It is urged, that superficial and general knowledge often tends to produce pedantry, and that persons who are only imperfectly learned are sometimes vain and presumptuous. With regard to the charge of pedantry, it can only be applied to the half-taught in manners, as well as in science; and, in such a refined period as this in which we live, it is scarcely possible that such a folly can flourish. What is sometimes called pedantry, indeed, may depend upon the ignorance of the many, as compared with the knowledge of the few; but the moment the language of science becomes the common language of refined society, every feeling of this kind must cease; and till that event takes place, the person must be very, very deficient in common sense, who endeavours to astonish by a parade of knowledge; and

who, being in possession of a light, chooses rather to employ it for dazzling the eyes of others, than to use it for his own guidance.

That persons who are only *beginning* to attend to the principles of science often overrate their acquirements and abilities, cannot be denied; but this is a circumstance of very little importance, and seldom of much permanence. In every well-regulated mind false confidence cannot be of any long duration. Vanity almost always carries with it a certain cure. Disappointment soon follows the ardent hopes of wild presumption, and, in a sound understanding, the conviction of having been once mistaken generally produces discretion and caution, which daily become more habitual, which direct the mind in its judgments, and which, when combined with feeling, become the foundation of a just and accurate taste.

All human knowledge is necessarily imperfect; but the further it extends, the better are its effects. No efforts made for the attainment of truth ought to be slighted. Lofty ideas are often connected by man even with his weakness and follies: how much more ought they to arise from his strength and his wisdom! His powers are often wasted in attempts to obtain trifles, which vanish or cease to delight at the moment they are in his possession; and we ought always to rejoice when those powers are applied to objects which are permanent, and connected with true glory. Man is formed for pure enjoyments; his duties are high, his destination is lofty; and he must, then, be most accused of ignorance and folly when he grovels in the dust, having wings which can carry him to the skies.

INTRODUCTORY LECTURE TO THE CHEMISTRY OF NATURE.*

Dependent upon the forms and beings of external nature for the gratification of our wants, and for many of our comforts and enjoyments, we habitually acquire, from individual experience, a certain degree of information concerning their operations and their changes.

This information, however, is extremely imperfect. The most acute and penetrating genius, unassisted by scientific methods, wholly fails in its attempts to trace effects to their causes; and an acquaintance with the minute relations and properties of natural objects, and the laws by which they are governed, can be obtained by philosophical study only; by an inquiry into natural science, into that system of extensive knowledge which has been accumulated in different times, and collected from a variety of sources, by multiplied observations, labour, and ingenuity.

Natural science is founded on minute critical views of the general order of events taking place upon our globe, corrected, enlarged, or exalted by experiments, in which the agents concerned are placed under new circumstances, and their diversified properties separately examined. The *body* of natural science, then, consists of *facts;* its governing spirit is analogy,—the

* [This Lecture intended to recommend especially the study of Chemistry as a philosophical pursuit to liberal minds, was written, as it is noted, on January 30, 1807, to be delivered the 31st.]

relation or resemblance of facts by which its different parts are connected, arranged, and employed, either for popular use, or for new speculative improvements.

The chemical phenomena of nature constitute the objects of one of the most extensive branches of the science. The parts of all known bodies are capable of new arrangements; and all the changes in their constitution, whether rapid or slow, whether the work of hours, of days, or of ages, whether grand or minute, are equally the subjects of chemistry. The study embraces a great number of principles and facts, various in their nature, importance, and applications. A general view of the order and plan of the course will, perhaps, not be considered as an improper introductory illustration. This view, from the multitude of objects which must be crowded together, will, I fear, be very tedious; but it is necessary, and, if you will attend to it, may remove some difficulties, and it may prevent disappointment; for it will explain how much of common and familiar philosophical detail will be introduced, the general arrangements to be adopted, and what new matter and new elucidations will be offered.

The order of nature is immediately dependent upon the continual transmutations and changes of external objects. The variety of the forms of things, their unceasing modifications, but for chemistry, would be unintelligible enigmas. The diversities of matter, the causes of its mutations, are perhaps the first amongst the subjects of speculation that press themselves upon the inquisitive mind; and they will likewise be the first to occupy our consideration.

The researches of modern chemistry, the methods of the experimental art, have demonstrated that all natural bodies consist of different arrangements or combinations

of a few simple parts or elements, and it is on the knowledge of the invariable properties and agencies with which these elements are endowed, that the whole of the demonstrative part of the science depends. Amidst their numerous alterations, the chemist is generally capable of arresting them, and of examining them in their pure forms, and in their different states of existence; whether as solids, as fluids, or as aëriform substances, they are almost equally within his power, equally capable of being investigated by experimental means. On this subject I shall enter only generally, illustrating it rather by striking examples than by minute details: common events even will afford a number of instances. Moisture, which falls from the atmosphere in rain is again dissolved by it, or enters into the composition of animal or vegetable bodies, or mineral formations; but when chemically examined, it still retains the same constitution, the same permanent properties. The coal in our fires is converted by combustion, into a peculiar species of air, which is dissolved by water, carried into the soil, and changed in the elaboratory of vegetable life; but the elementary matter may still be traced with precision—the same in weight, in quality, in essence.

Heat, the greatest, the most universal perhaps of natural agents, will next claim our attention. Some of the noblest of the works of modern chemical discovery are connected with this subject; and the same truths which led to the greatest extension of our mechanical powers ever invented, in the management and effects of steam, have likewise elucidated an immense number of natural phenomena, before perplexed and obscure. In this part of the course I shall detail the doctrines of Professor Black, and the later discoveries and facts of Dr. Herschel, Count Rumford, and Mr. Leslie, as far

as they claim any relation to the general subject. On this point our views may be materially assisted by experiment; and I shall endeavour to offer such sensible illustrations as may be clear and distinct. Natural appearances, however, and the great cycle of terrestrial changes, will afford a copious narrative of facts. It is on heat that the fluidity of water, the elasticity of air, and the form of the soil, depend. It penetrates every where, and is every where efficient. Terrible in its *partial* destructive and consuming agencies, it is admirable in its *general* beneficial and useful effects. The beauty and order of nature are connected with its operations; and the progress of vitality, as it were, follows the successions of periods and seasons, and the changes of temperature in the diurnal and annual motion of the earth and the sun.]

Light, much less powerful as a cause of chemical change, will occupy much less of our time. The experiments of the separation of its rays, and their different chemical effect in the pure forms, will afford some curious matter for discussion. The researches of Dr. Herschel have sufficiently shown the distinctness of light and heat. But as heat usually co-exists with light, it is not easy to determine clearly the operation of this last agent. It occasions, however, or at least influences, a great number of natural changes. Crystallizations, the alterations of colour of bodies, the health, and, ultimately, even the life, of vegetables, depend upon its agency; and, as M. Lavoisier has well observed, it is on the surface of the earth only, where the forms of matter are exposed to light, that organization, spontaneous motion, and sensation, exist.

Electricity will offer a more extensive field of information and discussion. That power, the demonstration of which, as identical with lightning and the cause of thunder, was one of the greatest philosophical triumphs

of the last century, there is every reason to believe, is not limited in its operation to the atmosphere, but is constantly producing the most important effects in the other great parts of our system. The galvanic phenomena, only lately identified as dependent upon the same principle, have afforded to us new and excellent instruments, and most powerful means of investigation, and have connected in a remarkable manner electricity and chemistry. The discoveries of Franklin, Volta, Galvani, and Walsh, and other philosophers in our own country, who have eminently enlightened the subject, will be successively examined.

In this department of the inquiry I shall be able to offer some novel views, and various original experiments. It would be improper for me to avoid mentioning my own labours; but I feel full confidence that I do not risk the imputation of vanity. The observations that I have been able to make will at least show the very intimate relation that exists between the electrical energies of bodies and their powers of chemical combination; and the processes will exhibit a variety of new methods of decomposition and analysis, which, I trust, will not be found wholly devoid of theoretical application and practical advantages.

The apparatus of Volta, analogous to the organ of the torpedo and the gymnotus electricus, produces, silently and slowly, the most astonishing changes. The appearances of fire and light, associated with all the early discoveries in electricity, and which rendered the facts popular, brilliant, and impressive, are far from being connected with its most important agencies. It is not by flashes, by explosions, and sparks, but by quiet, gradual, and almost unperceived operations, that it produces its greatest effects; and, generally diffused, like

heat, it perhaps, is equally active, equally important, in the economy of nature.

After having closed the consideration of the active and etherial powers, as they may justly be called, which are continually operating upon gross and ponderable matter, the next subjects for our inquiry will be the common arrangements of bodies in the three great divisions of the globe—the atmosphere, the ocean, and the solid surface of the earth.

Air, supposed in all the ancient systems of philosophy to be an uniform and immutable element, is now known to contain not merely different chemical compounds, but likewise different mechanical mixtures of various elementary substances. Its constitution will be experimentally demonstrated; both the early and the later researches will be examined; and it will be found, for the glory of our science, and our own country, that its composition was first accurately shown by a British philosopher still living;* and that after twenty-five years of error and doubt, his estimations have been universally admitted and adopted, both abroad and at home. The subject of the nature, constitution, and agencies of the atmosphere will furnish ample sources both of experimental and theoretical elucidation. The action of one of the constituent parts of air upon inflammable bodies is the cause of the beautiful and important phenomena of combustion: it is the medium by which the solar light and heat are transmitted to us, and their powerful agencies are dependent upon a peculiar state of its constituent parts. Unequally heated by the action of the sun upon the surface of the earth, different strata of air are constantly changing their places, and currents are established, which, modi-

* [Mr. Cavendish.]

fied by the rotation of the globe, produce all the varying phenomena of the winds.

The atmosphere, though the receptacle of all the elastic fluids formed or developed on the surface of the earth, is nevertheless uniform with regard to the proportions of its principal elements; and those parts of it which are absorbed by bodies, which are taken into the lungs of animals as an essential nourishment, are again supplied by a series of beautiful operations. In consequence of changes in the temperatures of different portions of air, a part of the water that they contain is often deposited in a state of minute division; and hence arise all the beautiful and varying appearances of clouds; hence snow and hail, and hence rain and dews, that supply the earth with vivifying moisture. All the particles of the atmosphere are active in forming combinations with water, and with substances contained in soils; and by means of its extensive and diversified operations the fertility of the earth is preserved, and she is rendered a fruitful mother of living beings.

The arrangements of the waters of the globe will follow in proper order, and their nature and changes will afford a variety of cases of chemical action.

In the great extent of the ocean an important series of effects are constantly taking place. Though a number of substances are carried into it from the land, yet by chemical operations it is preserved in an uniform state, and its saline and aqueous parts duly mixed together. Warmed by the solar heat, it diffuses its pure moisture through the atmosphere; agitated by the winds and tides, its waves are combined with air, which, dissolved at the surface, passes even to the remotest depths, and becomes a principle of vitality to the beings inhabiting them.

Our rivers and streams, which owe their remote origin to moisture carried by evaporation from the sea, undergo analogous changes; but, being in a constant state of motion, they are modified to a greater extent. Their composition is affected by the substances which constitute their beds; and their materials, after undergoing a variety of alterations, are either returned to the bosom of their parent ocean, or made subservient to the purposes of life in new forms.

The solid surface of the earth will next be considered. The theatre of all the grand changes occurring in nature, it is in itself comparatively fixed, and comparatively immutable, and the substances composing it are, above all others, endowed with invariable qualities. This part of the course will include the pure and elementary geology, freed from all cosmogenical inquiries, from all hypothetical generalizations, whether the dreams of ancient times, or the ingenious and beautiful visions of modern philosophers. On this subject I shall be able to introduce a number of original observations made upon the constitution of the strata of the earth, which will, perhaps, have a peculiar interest, as belonging principally to these islands; and they will be illustrated both by specimens of rocks, and by large coloured sketches.] ¶

The soil, the decomposed exterior crust of the earth, consists of finely divided matter, daily in a state of change from the operation of common natural agents; and when its parts are consolidated by the recent agency of water, it is considered as alluvial, or the latest class of rock formations.

The strata disposed in layers parallel to the horizon usually abound in the remains of shells, marine animals, and plants, of which very few classes are now existing: and these are the epizootic, or, as they are usually de-

nominated, the secondary strata. Their origin is connected with an obscure period of time, when the present land was covered by the water, and they remain as monuments of a grand and awful catastrophe that has happened to our globe.

The class of rocks composing the summits of the highest of our mountains, and extending to the remotest depths accessible to human observation, are crystallized masses, consisting of a few elementary materials, apparently rudely arranged, and yet bearing in their most imperfect parts characters by which they may be distinguished, and types marking their species. Free from any fragments, — containing no organic remains, they appear, at first view, as if exempt from the common law of decay, and from the operation of time; yet their external and superficial parts, where fully exposed, undergo chemical alterations; and, by the general effect of the inequalities of the foundations of the surface, a number of important changes are constantly produced. Earth is supplied from the mountains to the plains and valleys; by means of mountains a greater inequality of temperature is produced; water is supplied to the low countries, and the course of the winds modified.

In all this system, whether in its state of rest or of motion, the great end is the conservation of living nature. The laws of inorganic matter seem constantly active and efficient for no other purpose, and, amidst all the changes of the globe, *animation* rises unsubdued and supreme!

The last branch of these lectures will concern chemical operations, as far as they are connected with the powers of living systems. On this subject, as yet, little has been effected; and the materials, though important, are few and slender. The skirt only of the veil which

conceals these mysterious and sublime processes has been lifted up, and the grand view is as yet unknown.

Of vegetable chemistry, which has lately occupied a particular course of lectures, I shall have little to say; I shall confine myself merely to general views of its relations to the great chemical economy of nature.

The functions of animals will offer more extended objects of research. Digestion, nutrition, and, above all, respiration, will admit of various elucidations from the laws of chemistry; and, in whatever is known, a beautiful order, and an excellent adaptation of the means to the end will be found.

Such is the outline which I shall endeavour to fill up. After having given so extensive a detail of the objects to which the course will relate, it will be scarcely necessary for me to enter into any minute display of the importance or advantages of the study. You must have already felt and already weighed them; and it is far from my wish to attempt to seduce you to become partakers in a repast, which you may find rather coarse and homely fare, than a sumptuous and elegant entertainment. Some things, as I have said, will be new; but many will be old, or belong to the order of philosophical common-places. A few experiments will be upon a considerable scale, and connected with brilliant results; but a far greater number must inevitably be minute, will require attention to be seen and understood, and will be valuable only in consequence of their applications. The subject, likewise, I fear, will admit of few amusing details — nothing to awaken pleasantry —nothing to excite wit. There are no *anecdotes* of nature: these, indeed, belonged to the systems of the Greeks, and the nations of antiquity; but the philosophy of Bacon and Newton has fortunately excluded

them from our schools. The history of things, and their faithful representations, will be the only sources of interest; and the love of nature and of truth are almost the only feelings that can be gratified by the pursuits of this part of experimental knowledge.

In some respects, indeed, the chemistry of nature is superior to any other departments of the science. It is not much connected with laborious operations in crucibles, with the effects of mixture, the minute forms and combinations of artificial processes in phials, retorts, or alembics; but it is principally founded upon the observation of extensive and obvious changes; and its machinery is composed of the great forms and elements of the external world, which are at once objects of vulgar admiration, of imitation in art, and of poetical description. Sunshine, winds, vapours, clouds, rivers, and cataracts, are its prime agents; and the scenes of their operations, the diversified face of nature, the sky, the ocean, mountains, plains, and valleys.

In another point of view, it may perhaps be said to offer a peculiar source of interest to active and energetic minds. It is one of the few branches of experimental philosophy capable, as our methods now apply, of very exalted improvements; and the new instruments, in this science, are capable of most extensive applications, and, in the hands of ingenious men, will probably lead to discoveries as important, or even more important, than those made by the early philosophers of modern times, by the invention of the microscope and telescope, when new worlds of minute forms were developed by means of them upon the earth, and new grand worlds, and solar systems, discovered in the heavens. The methods of investigation have been ascertained, but, as yet, little used. We are, as it were, cul-

tivators in a new country; the woods, as yet, have only been cleared from the coast, but we have not penetrated into the interior fertile savannahs, nor to the grand mountain districts.

In general, the same arguments will apply to the study of this branch of science, and the various comprehensive departments of the great system of natural knowledge; and, in this respect, I can do little more than give a repetition of arguments, which I have already ventured to urge in favour of the popular and general study amongst the refined classes of society.

The superiority of modern over ancient times seems to be, in a great measure, connected with the state of our physical knowledge, and the chemical and mechanical inventions and arts dependent upon its principles; for in many other respects the nations of antiquity were, perhaps, our superiors rather than our equals. Greece and Rome had their heroes and conquerors, who extended their power over the best part of the globe; their poets and orators, who produced the most harmonious combinations of language; their artists, who formed the most excellent representations of strength, of grace, and of beauty; but the mass of the people were plunged in ignorance and barbarism. The operations connected with physical science were unknown. Natural knowledge was neglected: and the men who called themselves philosophers, inattentive to experiment, chiefly pursued vain speculations, and, in attempting to predict concerning all things, discovered nothing: in following a shadow, they neglected the substance. The highest degree of distinction was soon attained. Hope was anticipated by enjoyment. No new object of inquiry arose out of intellectual pursuits. Literature and the fine arts arrived at a degree of per-

fection beyond which even ambition had nothing to desire; and when the turbulence of war had ceased, when the restlessness of conquest had passed away, they became only as roses, strewing the path that led to luxury and ruin.

In these latter times, on the contrary, the dominion gained over nature, by the processes and arts of experiment, has contributed to the preservation of the mind in a continual state of activity. The exertions of unfettered genius have been constantly producing new fields for investigation. Literature has been an instrument of science; science has given new ideas and new combinations to literature; and even the objects of the imitative arts have been extended in consequence of experimental research. The mind has been at once strengthened and refined, and the equilibrium between reason and feeling preserved. Men of science, instead of worshipping idols existing in their own imaginations, have examined, with reverence and awe the substantial majesty of nature. Discovery has not visited them and disappeared again, like the flashes of lightning amidst the darkness of night; but it has slowly and quietly advanced, as the mild lustre of the morning, promising a glorious day.

INTRODUCTORY GEOLOGICAL LECTURE.*

So different are the exertions of the faculties of the mind, and so infinitely various the combinations of our ideas, that *the same objects* may be examined with the most opposite views, and considered under many diversified and beautiful relations.

It is on this fact of our nature, so familiar to every understanding, that the great extent and progression of science and philosophy depend. Hence their division into various branches, and hence the distinctness and accuracy of the different species of knowledge.

The planet that we inhabit may be considered, in its connection with the general system of the universe, as acted upon by gravitation, and revolving round the sun. It may be considered as the abode of organization and life, covered with vegetables, and peopled with animals. Or it may be studied as composed of different inorganic parts, variously arranged, and subservient to different uses.

It is under the last point of view that it is the subject of *Geology*. This word is derived from the Greek lan-

* [This and the following Lecture on Geology were the first and second of the course which the author delivered in 1811, founded on an earlier one of 1805; when, as he himself says, the science of Geology was in its feeble infancy; when no one had preceded him in this country in lecturing on the subject; not a single elementary book had been written on it; and when he had to collect his materials from various remote sources, and from disjointed members, construct a body of geological knowledge.]

guage: it signifies *science of the earth;* but its acceptation is limited, and it is applied only to the branch of knowledge relating to the nature, position, and changes of the bodies that compose the *known* parts of the surface of the globe.

The outlines of the science are plain and obvious, and they may be illustrated even by common observation from a superficial view of nature. I shall attempt a delineation of them, which I hope will be found an appropriate introduction to the study of the science, and I shall point out the order in which they will be considered in these lectures.

The first impressions received from the exterior of the globe are those of diversity, variety, and beauty. Hills, valleys, and plains, appear covered with different soils, and affording different vegetables. Mountain chains are seen presenting irregular summits, bare or capped with snow, or emitting volcanic fires; and their foundations form the beds of rivers, or the shores of lakes, seas, or the ocean.

In different mountains and rocks, there are two remarkable distinctions of arrangement. Some are irregularly heaped together in large masses, or layers, which are divided almost perpendicularly to the surface. Others are arranged in bands, or strata, parallel, or very slightly inclined to the horizon.

The first consist, for the most part, of crystalline stony matter; they contain few fragments, and exhibit few vestiges of a former order of things: these are called primary rocks.

The second usually contain abundance of chemical deposits, water-worn stones, sand, and even clay, and they often abound in vegetable remains, and the exuviæ of marine animals: these are called the secondary rocks.

Both these great orders contain dykes, or veins, which are more or less perpendicular; and which have been fissures, or chasms, filled with different substances, embracing a variety of metallic ores.

The primary and secondary rocks; their transitions into, or relations to each other; and the different substances they contain, are the first and most important objects of study in geological science, and they will be the first to occupy our attention in this course of lectures.

The variety, the shades of difference, seem almost infinite; yet their relations are capable of becoming the objects of distinct study. The rocks of different districts, where there is a considerable extent of surface, are generally found of the same species; similar varieties have similar associations in climates the most distant, and the chasms or veins that they infold usually contain the same metals, and the same crystallized bodies.

The arrangements of rocks and mountains in nature, and of the minerals they contain, are admirably adapted to the economy of things; and these arrangements will be pointed out and discussed. The metallic ores, so useful in the arts of life, which would be noxious if distributed over the surface of the globe, are concealed within its bosom, where they serve to awaken and employ human industry and ingenuity. The irregularities of the surface, so calculated to delight the eye by their sublimity or their beauty, are absolutely essential to the order of the system. They diversify the temperature of the earth; the cooling agency of the high lands is a cause of rain and vivifying dews; the water raised in vapour from the ocean is condensed on their summits, and flows in springs, and streams, and rivers, to produce vegetation, and multiply life in valleys and plains.

After considering the existing order of things in the forms which, at the moment, appear permanent, the next step in the inquiry will be, the laws of their alterations. On this subject the human powers are necessarily limited; we have as yet penetrated to a small depth only below the surface; and there may be an interior mechanism in the centre, of which we have no knowledge. The effects of heat, light, air, and water, upon the surface, are almost the only circumstances which we are capable of accurately studying; and even with respect to these our sphere of observation is very small. The works of ages cannot be judged of, except very imperfectly, by their effects, in hours or days; the laws of Infinite Wisdom cannot be fully estimated by finite intelligence; yet there is a glory in the effort, and delight and instruction in the result.

The primary and secondary rocks, which form the known solid parts of the globe, undergo at their surfaces a continued series of changes; and the causes of their decomposition are the alterations of temperature to which they are exposed, assisted by the chemical and mechanical agency of water, and the attraction of their constituent parts for principles contained in the atmosphere. Firm and immutable at their bases, the parts of our mountains, wherever they are exposed to air and moisture, lose their durability and their stony texture, in consequence of chemical and electrical agencies, and become subservient to the production and renovation of soils. From the decomposition of a variety of rocks, and from the mixture of their elements by the agency of water, of streams and rivers, varieties of earths result, fitted for all the different modifications of vegetable life. In plains, in valleys, and on the low hills and moun-

tains, they support plants and trees, subservient to the nourishment and shelter of the superior animals, and to the uses of man. On heights, where the larger plants are incapable of growing, in consequence of the intensity of the cold, or the force of the blast, grasses are still found, and vegetable life extends its empire, by means of mosses and lichens, to the limits of perpetual snow.

When the effects for which decomposition seems principally to operate have been attained, the causes lose their energy, and the surface is in a great measure defended by vegetation, and by the vegetable earth, from any new action of the elements, and novel matter even is accumulated upon it from water and air, which at first were the principles of its decay.

By the degradation of surfaces of rocks, fertile slopes are formed, where before there were only barren precipices. Lakes are filled up, the lower parts of the beds of rivers are diminished, and a finely divided earth is transported, by the mechanical agency of water, from bleak or inaccessible mountains, to supply the waste of soil in cultivated valleys and plains.

Amidst the changes and circulation of matter, a certain quantity of the solid materials of the land is carried into the sea; but in this circumstance, when fairly considered, there is no principle of general destruction, and there are a number of counterbalancing agencies. Low islands are forming, or constantly increasing, at the mouths of great rivers, from the opposing agencies of the tide and the stream; coral rocks are continually forming in the great extent of the ocean, and these are already the bases of many fertile islands in the Pacific; and subterraneous and submarine fires are active in extending land: so that the principle of change seems

essential in all terrestrial nature; but, by an equilibrium of powers, by the coincidence of effects, the system continues the same; and the order by which the globe is preserved, fitted for the purposes of life, appears as fixed and unalterable as that which insures the reproduction and continuance of the tribes of living beings, its inhabitants.

We are carried by anticipation from the present to the future, and the imagination is equally active with respect to the past. In considering the phenomena of geology, it is impossible to avoid conjectures concerning the former alterations of the globe. The productions of the sea are found embedded in high mountains; the whole of the surface appeals to us in the intelligible language of the Roman poet, which may be thus translated:—

> "Remains that to the waters owe their birth
> Occur in rocks beneath the solid earth:
> Where our rich fields their varied face display,
> Once in proud triumph flow'd the azure sea;
> And in the change of things, and lapse of time,
> The conquering waves have form'd another clime;
> And where another land its verdure spread
> Is now the moving ocean's tranquil bed."

But on what great causes have these wonderful changes depended, by what laws, or according to what principles, have they been produced? This inquiry is a most interesting, I may say, a most sublime part of geology. It generally occupies the first place in systematic works: I shall treat of it in the last place in these lectures, because it will always be a hypothetical investigation. It cannot be in any way made a series of facts—its productions must be probable analogies.

The most striking and brilliant view of the subject is that which was developed in its first form by the genius

of Hooke, and which has ripened into what is usually called the Plutonic theory. In this theory all the phenomena of geology are supposed the result of an uniform system, in which there has been no derangement, but one constant order. The land, it is said, is continually degrading and decomposing by the agency of water, and, in the course of cycles of ages, must be entirely destroyed. But there is an antagonist power of renovation—*fire*, which, acting beneath the bottom of the sea, is continually raising land, from which continents and islands result. Our rocks are crystallized or consolidated, and must, say the advocates for this opinion, have been once fluid or soft; and fire is the only agent adequate to such an effect, which, acting under the pressure of the ocean, must produce results very different from those which it occasions in the free atmosphere.

According to the Plutonic notion, all our rocks have been formerly the materials of another land, and the organic remains they contain are considered as so many proofs of this circumstance. In this system, decay and renovation are conceived to be perfectly balanced: water degrades; fire reproduces; and they are imagined to be opposed to each other, like the evil and good principles of the Persian mythology, Arhimanes and Ormuz, the destroying and creative genii.

From what I read a few minutes ago, it is evident that, in referring to the actual changes now taking place upon the globe, we must admit the operation of causes similar to those adopted in the Plutonic hypothesis; but it is a matter of doubt and of discussion whether they must be admitted as universal.

One great difficulty opposed to the ingenious theory, was the source of heat. But this may be accounted for

by supposing the interior of the globe composed of the metals of the earths, which the agency of air and water might cause to burn into rocks; and even the re-production of these metals may be conceived to depend upon electrical polarities in the earth; and in this manner an harmonious order may be assumed: but though the idea is one which I have myself ventured to throw out, I cannot avoid saying that it rests on pure speculation. It does not command our assent, nor has it for me that high degree of probability which necessarily induces conviction.

The view which is particularly opposed to the Plutonic is the Neptunian, and it is sanctioned by the authority of Werner, Kirwan, and De Luc. In this hypothesis it is conceived that all rocks are depositions or crystallizations from a solution in an aqueous menstruum, and that the secondary rocks were the latest depositions, being formed after the ocean was peopled with living beings. No order is conceived corresponding to the existing order of things; the whole system is founded upon the solvent powers of water.—It is a speculation very remarkable for its simplicity.

Besides the Plutonic hypothesis, which considers rocks as the result of an existing order, and the Neptunian, which regards them as products of a slow process of creation and deposition from a chaotic fluid, there are other views, in which the present state of things is supposed to have resulted from a great and extraordinary series of events, by which the ocean was carried over the land, and the secondary rocks deposited upon the primary ones. Leibnitz and Whiston refer this great revolution to the agency of a comet, by which the tides were raised above the mountains, and

carried round the earth, and by which the water was heated so as to gain new solvent powers; and they connect this event with the sacred and profane history of early times.

In examining these different views, I shall endeavour to discuss the evidences on which they rest, and to estimate the degree of probability of the different arguments brought forward to support them. On such a subject doubt is not merely excusable, it is, in fact, salutary. It is only by reasoning upon the operations of chemistry that we can hope to gain any just theory of the formation of rocks; and chemistry is every day gaining new instruments, and exhibiting to us new substances and powers; and the perfection of this science cannot fail to enlarge our views of the grand operations of nature.

The most active imagination must rest somewhere: there is some point in which even a circle must be begun; and all the evidences deduced from the face of nature would incline one to believe, that the beginning of the existing order of things cannot be placed further back than the period attributed to it in the sacred writings; and it is this order only which it is in our power accurately to study.

In this order the two grand circumstances are,

1st, That the secondary rocks have been materially altered by causes acting from above. Strata have been swept away, valleys opened, cliffs laid bare, and yet the parallelism of the parts preserved.

2d, That the primary rocks have been deranged by causes acting from below; they are irregular, their layers disturbed and diversified, and there is no distinct parallelism.

It seems absolutely necessary to introduce more than

one system of causes for the changes that have taken place. Fire renders bodies fluid, but it increases the solvent powers of water to a wonderful extent; and all substances possessed of chemical action on each other have their energies exalted by heat. It has been too much the fashion in philosophy to refer operations and effects to single agencies; but there are, in fact, in nature two grand species of relationships between phenomena: in one an infinite variety of effects is produced by a single cause; in the other a great variety of causes is subservient to one effect. Both are equally important, and equally worthy of being studied; though the last has been least attended to, as the inquiry is more laborious, and the results less attainable. Instances of it may, however, every where be found parallel to those in geology. A variety of rays co-operate to produce the simple sensation of pure light; the numerous gravitating agencies of the planets and their satellites upon each other, and upon the sun, produce the simple effect of regular, harmonious, and invariable revolutions; the functions of animal bodies are supported by various nourishment, and by various sets of organs; and almost all the principles of matter, in their various combinations, are made essential to the existence and the pleasures of one being.

In these things there is the nicest adaptation, an order calculated to awaken the strongest admiration. We ought never to judge of nature by the generalizations which exist in our own fancy. We are compelled to seek for simplicity on account of the weakness of our own powers. We are incapable of giving perfection and utility to complicated machines; and we are generally most impressed by that which approaches nearest to, and which most resembles, the best of our own productions. But

man is merely the imitator, the servant, and interpreter, of nature: he labours in vain when he attempts to reason concerning the ultimate tendency of her works from that of his own. He is the slave of time: her operations are in eternity, and high faculties are required to catch even a glimpse of the wise and wonderful laws by which they are governed.

With the critical examination of the speculations and hypotheses on geology I shall conclude the course. I shall spare no labour; I shall employ all my feeble powers to make the subjects of it intelligible and useful; but lectures, even in their best and most popular form, even when they most awaken interest and arrest the attention, are wholly inadequate to fix in the mind the principles and bases of science. They may sometimes, indeed, in this case excite the uninformed to inquiry, and communicate general views; but they can be subservient to useful and extensive knowledge only when assisted by previous or collateral study of the subject to which they relate. It is for this reason that I urge on those of my audience to whom the science of geology is yet new, and who may really wish to become acquainted with it as students, the necessity of acquiring particular information by the examination of specimens, and by a course of reading.

It is not necessary in the study of mineral bodies in a geological point of view, to enter at once upon the consideration of the whole extent of the fossil productions of the earth. The principal rocks, which form the great foundations of the surface, are comparatively few in number, and may be very easily procured, and at an inconsiderable expense. The large sums of money which are often laid out in cabinets are usually devoted to the collection of rare and uncommon

minerals; but these substances, though greatly interesting to the mineralogist and chemist, are comparatively of little importance to the geologist, whose object is to study the usual productions and great facts of nature, rather than her accidental combinations and curious irregularities.

The knowledge of the external properties of the common rocks, considered as fragments, is a necessary introduction to the study of the earth. But it must be always remembered, that mineralogy ought merely to be a preparation for geology, and considered merely as affording the characters by which its mysteries are deciphered; and that it is in the great arrangements of nature, and not in the details of the museum, that the facts and the foundations of the science must be sought for and examined.

The study of the natural arrangements of rocks may, at first view, appear a very difficult and extensive labour, and to some persons an impracticable one; but to gain a general acquaintance with the subject it is not necessary to examine a great variety of districts, or a great extent of country. Our own island contains all the important species of strata, and that often in a very small compass, and in places which are easily accessible and in which the arrangement is distinct. In Cornwall alone almost all the same geological formations as those found in the Alps, in Saxony, and in Siberia occur, and in the northern counties and western coast of Scotland the most interesting varieties of secondary and primary rocks may be found in a space of a few square miles in extent, and even at a smaller distance within a hundred miles of the metropolis. In Leicestershire there is a similar arrangement; and in a journey of a single day the peaks of granite of Mount Sorrel, the secondary

rocks of Chawood Forest, and the coal strata and their formations, may all be easily attained.

In studying the natural appearances of rocks, much various information and many valuable hints may be derived from the examination of the descriptive writings of geological travellers; and there are many excellent works of this kind, developing correct views, and combining amusement with instruction. As a book most relating to the geology of our own country, I can with pleasure recommend the mineralogy of the Scottish islands by Professor Jameson. His descriptions are executed with correctness and address. I am able to bear testimony to the accuracy of many of his statements; and, whenever he has studied minutely or with labour, he is always ingenious and profound. Amongst the works which relate to foreign countries, it is unnecessary to dwell upon those of Humboldt; they have been recently brought forward in our most popular journals, and their merits ably displayed. The publications of Dolomieu, likewise, occupy a distinguished rank. This celebrated man was possessed of the true love of geology, and was guided in his researches by the most philosophical spirit. His writings, particularly those on the Lipari Islands, are distinguished not merely by accuracy of description, but likewise by a peculiar justness of thought and happiness of deduction. He is not a rapid traveller, who has merely sketched the outlines of objects; but he has studied them deeply, and examined their minute parts, their bearings and relations; and his pictures are equally valuable for their accuracy and their strength.

Of a kindred character are the descriptions of M. de Saussure. Educated amidst the magnificent scenery of the Alps, this illustrious person felt in his earliest

days the warmest admiration of the study, and his whole life was more or less devoted to it. Possessing from nature a penetrating genius, he assisted its efforts by all the refinements and resources of science. In his researches he spared no labour, and yielded nothing to the common sentiment of self-love. A constant inhabitant of the mountains, he has exceeded all other writers in his descriptions of them. His delineations are equally vivid and correct, and, as far as mere language is capable, they awaken pictures in the mind. De Saussure has presented the rare instance of a powerful imagination associated with the coolest judgment; of the brilliancy of ideas and feelings of the poet, connected with minute research and deep sagacity of the philosopher.

In speculative geology, the essays of Mr. Kirwan offer an extended view of the Neptunian hypothesis; and this excellent and learned philosopher has employed all his talent to support what he conceives an orthodox system of the earth, and to overturn the Plutonic heresy. M. de Luc has lately published a work of a kindred character, which demonstrates equally the vigour of his mind and the powers of his body. The ardour of this veteran in science for the pursuit of knowledge seems to increase with his age. I cannot always agree with him in opinion; but I admire the spirit with which he pursues his subject, and the unsubdued energies of his imagination.

The best view of the Plutonic theory in existence is owing to Professor Playfair, who has given to the ideas of Dr. Hutton, the ingenious founder of the doctrine, a new, a more philosophical, and a beautiful form. Dr. Hutton's system, as delivered in his original work, though marked by grandeur of view, and felicity

of induction, and copiousness of fact, is perplexed and obscure in detail: the arrangement is unhappy, and but little calculated to facilitate the knowledge of the subject. In Mr. Playfair's hands, which have sometimes altered, and sometimes created, the theory loses its character of a confused effort of gigantic but ill-directed power, and becomes impressive from its simplicity, and seductive from its elegance; and is rich in instances of noble philosophical eloquence.

From what has been said of the nature and methods of the study of geology, it is evident that the accurate pursuit of it must occupy a certain portion of time, and demand some labour and attention; and a fair question may be asked, What are its practical uses? What advantages are likely to arise from it? What interests will it promote? On this point I might undoubtedly shelter myself under the proposition, that "all knowledge is highly beneficial;" that whatever can awaken intellectual pleasure, or convey more exalted views of nature, or of the human talents, is truly worthy of our cultivation, and fitted for our faculties. But independent of such considerations, regarded merely as a profitable and useful science, I may fairly say that geology is exceedingly worthy of being cultivated; and a few details will be sufficient to prove that the information to be derived from it is often applicable to important purposes, and may, in a number of instances, be made subservient to the wants of life.

Fixed upon the earth, and dependent for our support and existence upon the various objects surrounding us, many of our necessities are supplied, and some of our highest comforts produced, by the application of substances found in the mineral kingdom.

The soils from which our vegetable nourishment is

raised, the stones of which our habitations are formed, the fuel we employ for so many purposes, and the metals so absolutely essential to civilized man, are all objects of geology; and as this science treats of their nature, arrangement, and association, it is evidently the most capable of affording useful discoveries with regard to their localities, occurrence, and readiest application. I have already mentioned that there is an order in the position of rocks, by which certain species are almost always found accompanying each other, and occupying the same district. In a mountainous country, for instance, if a rock of this nature occurred which is *serpentine*, we might be almost certain that this substance, which is *soap-rock*, would be somewhere found in it, and that this fossil, which is micaceous schist, would not be far distant. But in such a position it would be in vain to search for shell-limestone, or coal. Again, where soft shell-limestone occurs, there is a strong presumption that soft black shale or loose sandstone will be found in some contiguous spot; and in such country, there is little doubt that, at some depth, or in some direction, fossil coal would be discovered.

These circumstances are fundamental facts of the science, and the ready application of them will be immediately evident. The person who is digging for pit-coal, if he meets beneath the soil serpentine, or micaceous or granite-rock, if acquainted with the arrangement and nature of strata, will be immediately instructed to give over his labour, and spare useless expense. But should he find sandstone,—a substance which, to an uninstructed eye, appears of much the same nature as granite,—it affords him some encouragement to proceed in his researches; and a yellow or red ferruginous sandstone, or a fine-grained white sandstone, or soft slate,

bearing impressions of vegetable leaves, would offer very strong indications of the substance sought for; for these strata are generally immediately incumbent on coal. Similar reasoning may be applied to metallic veins. The metals seldom or never occur in rocks of serpentine, of sienite, or soft coaly schist, nor in sandstone, nor in basalt; but they may be looked for in soft granite, in hard schist, and in a hard shell-limestone. And if in granite or schist a vein of white stone is found running in a direction from east to west, there is much probability that in some part of its depth it may afford useful metal. And if veins of spar occur in rocks, partly hollow, and partly filled with a yellow substance of this kind, which, in Cornwall, is called Gossan, it may be almost concluded that such veins will be productive; and the larger the quantity of Gossan, the better the indication. Some very great losses and failures have often taken place in mining from ignorance in the directors of the common facts of geology. I shall mention a remarkable instance that took place in Somersetshire. Some miners from Cornwall were employed in working a rich copper-vein, near Nether Stowey. At a certain depth, the vein was crossed by a dike of stone. The miners cut in their accustomed direction, expecting immediately to reach the vein; but their efforts were wholly unsuccessful, and it was not till after some weeks, and much expenditure of money and labour, that the object was attained. The reason of their failure was, that the arrangement of dikes in the primary county of Cornwall, and in the secondary county of Somersetshire, is very different. In the one, the vein cut through almost always appears shifted; and in the other it maintains its perpendicular direction. And the mere knowledge of this fact, which is almost

general for the different districts, would have ensured the success of the operation.

A number of instances of the same kind might be adduced. And the science is equally applicable in a number of other arts and professions. It ought to be particularly studied by the engineer, who is employed in the construction of canals, or docks, or fortifications, as certain strata, exceedingly hard, often alternate with others that are very soft, and easily cut through; and, by a knowledge of their different positions and relations, much unnecessary labour and expense may be often avoided.

The drainer, in order to make his operations successful, ought to be minutely acquainted with the arrangements of the rocks in the district from which the springs arise, which it is his business to divert; and he ought to pay particular attention to the nature and position of *dikes;* for they often intersect soft strata, and stop the course of the water, and render all his operations useless, till they are discovered and penetrated.

The farmer and the improver of land even, may often derive from geology very useful instruction with regard to the position of limestone, marl, and clays, their appearance, and the nearest places whence they may be procured. And, lastly, even the architect may often benefit by this science. Of the strata which afford stones employed in building, some parts are much more liable to decay than others, and the external character affords the indication. Many rocks, exceedingly beautiful and tempting to the eye, and easily cut through, are often very liable to decomposition,—are easily destroyed by common natural agents, and their relations to permanency can only be known by scientific observation. I can mention two remarkable instances in which decom-

posing stones have been unfortunately employed in the construction of considerable edifices, which, in consequence, are very rapidly falling into decay. The one is Chester cathedral, which is constructed of ferruginous sandstone; and, by the action of water and air, all the exterior ornaments, and nearly a half of the surface of this venerable structure, are destroyed. The other is the library of Trinity College, Dublin, which must have been a most beautiful building, but which, from decomposition, is rapidly losing all its elegance of architecture. And the circumstance is the more singular, as the principal rocks in the vicinity are beautiful and permanent granites; and, by some unfortunate circumstance, the materials selected for this edifice must have been brought from some distance, and probably at a great expense.

It will be unnecessary to pursue these statements to any great extent. Sufficient has, I trust, been said to prove that the science may be of national as well as of individual advantage,—and, at least, to establish its utility. It is far from my wish to endeavour to exalt geology to a higher rank than it ought to occupy, or to attempt to raise it unfairly above the other branches of physical knowledge; but I should be unjust to my subject were I not to state some of the peculiar advantages which it possesses as a science of contemplation, and as a series of important truths, unfolding some of the most beautiful and important parts of the economy of nature.

Of all material objects that can employ our attention, those that are nearest to us ought to excite the warmest and most immediate interest; and, after man and animated nature, no subject of physical inquiry bears a more distinct relation to us than the place of our abode—the earth, to which we are necessarily attached, and the

mechanism of which is intimately connected with our powers, our enjoyments, and even our existence. The more general study of the science, and the constitution of the globe, affords some very beautiful and sublime views, which could never be gained from the common observation of external nature. It explains the importance of the variety and irregularities which it exhibits; and demonstrates that no parts are useless; and that the causes which apparently produce destruction and disorder are, in fact, in the general series, connected with the renovation and support of the system. If the interest of this species of knowledge is considerable, the *facility* of acquiring it ought, at least, to be a motive why it should be pursued. It requires no laborious or continued investigation; no expensive or complicated apparatus: no minute processes upon the unknown properties of matter. It demands only an inquiring understanding, an acquaintance with certain simple elements of knowledge, and a mind alive to the facts which are almost every where presented in nature.

Geology is yet in an infant state. The great arrangements only are known; and whoever furnishes to it new histories or facts becomes an improver of the science. The ease with which discoveries are made ought, undoubtedly, to fix the attention of active spirits. In this department of knowledge there are fields of investigation yet unexplored, rich in fact and theory, and the subject is one equally fitted for an exertion of the memory, the reason, and the imagination.

The person who is attached to geological inquiries can scarcely ever want objects of employment and of interest. The ground on which he treads; the country which surrounds him; and even the rocks and stones, removed from their natural positions by art, are all ca-

pable of affording him some degree of amusement. And every new mine and quarry that is opened; every new surface of the earth that is laid bare; and every new country that is discovered, opens novel sources of information. In travelling he is interested in a pursuit which must constantly preserve the mind awake to the scenes presented to it. And the beauty, the majesty, the sublimity of the great forms of nature must necessarily be enhanced by the contemplation of their order, their mutual dependence, their connexion as a whole. The imagery of a mountain country, which is the very theatre of the science, is, in almost all cases, highly impressive and delightful; but a new and nobler species of enjoyment arises in the mind when the arrangement in it, its uses and its subserviency to life, are considered. To the geological inquirer, every mountain chain offers decided proofs of the great alterations that the globe has undergone. The most sublime speculations are awakened; the mind is carried into past ages; new forms of existence are presented to it, and a boundless inquiry; the destruction of a former order of things, and a system arranged with harmony, filled with beauty and life, formed from its elements, and established on its ruins.

GEOLOGY.—LECTURE II.

The plan which I propose to adopt in treating of geology, and which I announced in the introductory Lecture, will, I feel, offer much less amusement, than those that are usually followed.

To connect the facts belonging to the mechanism of the earth with a general hypothesis of cosmogony, and to make them subservient to speculative views, offers more pleasing associations to the memory, and more brilliant pictures to the imagination, than the mere simple developments of the real order and existing arrangements of nature.

The phenomena of the external world, as well as the passions and feelings of the human mind, are most impressive, when they are connected by distant and varied analogies, and tinted with the brilliant hues of fancy.

But the end of science ought to be *truth;* simple, unadorned truth,—and her great object, utility. And, in the pursuit of truth, that which was at first a labour, soon becomes a pleasure; for the results are permanent, —the effects important; and the delight that the mind receives, constantly increases. It is neither capricious nor transitory; for it is founded upon the operations of laws which are wisely and benevolently constituted, and which are eternal in their operation.

The contemplation of the general exterior of the earth, shows that even its irregularities are happily disposed. The bleak and elevated mountain is contrasted with the

sheltered and deep valley; the shaggy and wooded hill, with the level and cultivated plain; and the bright and even expanse of sea or sky, with the deep-tinted and unequal land. Scenes abound in all parts, harmonious; and more delightful from being warm with animation, and full of the forms of life.

On penetrating the surface, however, a new and altogether different order of things, is presented to our attention. All is dark and silent. Soils, earthy strata, and rocks are blended together, apparently without symmetry or beauty. Veins of metallic ores and of crystallized stones intersect them in different directions —and by a transient examination, deformity and disorder only are perceptible in the subterraneous mineral kingdom.

This effect of confusion, however, soon ceases in the investigating mind. For, by continued observation, and sagacious comparison, a certain arrangement is perceived even in these rudest of the forms of matter. A distant analogy appears between their parts, and their utility and importance in the general system of nature, is gradually unfolded; becoming clearer and clearer, till at length it produces full and pleasing conviction.

The orders of rocks that compose the known part of the surface of the earth, are very few; and even the species are not numerous;—but the varieties are almost infinite.

The minute study of varieties, is, however, seldom necessary; except in cases where they are connected with the transition or passage of one into another. Usually they present the same characters; speak the same language; tell the same tale.

It is upon the distinct outlines in nature, the marked and well-defined differences that geology truly depends;

and for accuracy of classification, and facility of inquiry, two kinds of characters at least are required.

The first characters are those gained from the minute examination of insulated specimens; from the inherent qualities which belong to the smallest fragment containing all the elements of the rock.

The second are the characters of the rock considered as a great mass, or as composed of parts bearing to each other a determinate and ascertainable relation.

In the first series, the principal properties to be attended to, are the figure and appearance of fracture; the crystallizations, if any exist, the specific weight, the hardness, and the relation to magnetic polarity and electricity, and to the power of conducting heat,—to taste, to smell, and to touch.

In insulated geological specimens, the natural fractures ought to be preserved; and two new fractures, one parallel to the horizon, and the other perpendicular to it, should be made; and an anciently-exposed surface ought to be suffered to remain.

All this I know is contrary to the method of the greater number of the Wernerians, who give to their specimens, however different, the same square form; and make on every side a new fracture, which answers very well in mineralogy for cabinet specimens; but which, in geology, destroys very important indications. For, in this science, the specimen ought only to be an assistance to the study of the rock; and in rocks, fresh fractures are seldom to be expected; they present chiefly water-worn surfaces, and decomposing points, and irregular outlines.

In examining the fracture of a rock, if any small irregularities of colour or form appear, the eye should be assisted by a glass (and where large, but imperfect ill-

defined crystals exist, an attempt should be made to fracture them, in the direction of the parallel and transverse lines which they present,) in order to ascertain, if possible, the primitive form. And for this purpose, a common penknife and a small hammer may be used.

The specific gravity, or the relation of the weight to that of water, may be known by ascertaining what weight of water a given weight of the fossil will displace. The magnetic polarity (if any) may be ascertained by a small needle. The electrical power, by rubbing the specimen with silk, or by heating it. The hardness may be judged of by the knife, or by the use of a ring or plate, containing a series of stones, differing in hardness from the diamond to calcareous spar. The other qualities are obvious, and require no elucidation of method.

In determining the nature of a particular rock, a very few characters usually are adequate; often, indeed, a single one is sufficient. Habitual and attentive observation will soon enable the student to catch, by a single glance of the eye, or a touch of the hand, the quality which marks the *greater number of common geological species;* and the complication of method, isprincipally necessary only in detecting new varieties.

All the specimens necessary for elucidating the minute characters of geology, are to be found in the museum of this Institution;* and I shall continually have occasion to refer to them, and I shall mention their characteristic properties. On this point, unfortunately no appeal can be made to the senses at the time of the description; but the bodies themselves may be examined minutely by those who may consider the study worthy of their attention.

* [Royal Institution.]

The study of rocks as masses, require infinitely less preparation, and less tedious detail of minute practices. Each species has an aspect and a general series of characters peculiar to itself; and which, when attentively examined, may in many cases be made even at considerable distances, an accurate indication of its nature.

The form of the outline, the colour, the interruptions of the surface, the lines of the strata or blocks, and the magnitude of the projecting or retiring angles, are all amongst the grand external characteristics. Instruments are seldom required for assisting in the discovery of them; and indeed almost the only ones that can be employed, are a pocket telescope, a small quadrant for discovering angles, a barometer for ascertaining heights, and a measuring staff.

The study of the aspect of rocks and mountains, is one of the most delightful departments of the science, and it is constantly connected with the new, the diversified, the beautiful, and the sublime in nature.

In this room it can be illustrated by feeble and imperfect sketches only; but these will be adequate to exhibit the important facts;—they will point out distinctly the methods and the nature of the inquiry, and the arrangements most worthy of being examined.

On the point of the aspect of rocks and mountains, the views of the geologist are directed to the same grand objects as those of the poet and the painter. But science makes distinct what taste would require to be obscure; its elements are collected only from the simple and permanent, and it leaves to the arts of imagination the charms and graces of the indefinite and the mutable.

In proceeding to consider our subject,—the arrangement of rocks in nature,—I shall adopt the division, to

which I referred in the last Lecture, into primary and secondary; but to prevent misconception of the uses of the terms I shall offer a few observations upon them.

When the word primitive or primary was first adopted by Lehman in the science, it signified the unaltered matter of the globe,—the matter in which no vestiges of a former order analogous to the existing order of things were to be found. This meaning has, however, gradually been changed, and the term is now often applied to all rocks that do not contain organic remains. And in consequence it is often made use of to denote rocks that abound in fragments derived from the destruction of other rocks: — thus it is not uncommon to hear primary sand-stones spoken of.

In this application I venture to disclaim the use of the words; I shall adhere to the first signification. Whenever strata or rocks contain any vestiges of destruction, or renovation, I shall consider them as secondary, and by dividing the two classes into different orders all the necessary distinctions may, I am convinced, be observed.

It is but paying a just tribute of respect to Lehman, to whom we owe so much,—that of preserving the purity of his definition. It is greatly to his glory that fifty years have passed away of continued progress in the science, and yet his general classification still retains all its truth and utility.

Primary rocks are distributed in considerable masses or strata, and constitute a great part of the known solid matter of the globe. They are found at the remotest depths below the surface, and form by far the greatest portion of the highest mountain chains. Of the orders in this class the granitic rocks, from their

position, extent, and importance demand the first attention.

Here are various granites:—the name signifies granulated,—and when superficially examined, the stone appears as a number of small fragments, cemented together; but upon minute inspection, it is found to consist of three different bodies united by crystallization, and inserted as it were mechanically into each other. These bodies are quartz, feldspar, and mica.*

Granitic rocks are usually found in large blocks accumulated together without distinct order and possessing unequal edges. The blocks generally approach in form to the cube. Granite sometimes occurs in layers; in this case it is called gneiss, and the plates of mica appear interwoven upon extensive surfaces which are arranged at intervals between the blended feldspar and the quartz.

In this picture the common aspect of the granite is exhibited.

INSTANCE.†

The aspect of granite is well expressed in every part of this view. No rock is grander in form or more sublime in structure. And placed at the western extremity of Great Britain, it seems well adapted from its magnitude, solidity and strength to resist the force of the waves of the Atlantic, and to prevent the encroachment of the ocean upon the land.

The feldspar is found of different colours in granite,

* [Merely notes for the description of the minerals constituting the compound rocks occur in the written lecture; it is useless to insert them; the reader, who is not acquainted with the mineral substances mentioned, will find them described in any elementary work on mineralogy.]

† [This I believe was a painting of the granite cliffs of the Land's End in Cornwall, by Mr. Webster, from a sketch by the author.]

—yellow, brown, red, &c. Thus in the granite of Pompey's pillar, the feldspar is red.

Granites sometimes contain another constituent part, which is schorl, and the mica is often so small in quantity as to be scarcely perceptible, and in this case the rock appears as a mixture of crystals of feldspar and quartz.

Granite, as to its texture, is one of the firmest of stones, and one in general little liable to decomposition and decay. Most of the great edifices of antiquity, that have been least altered in their forms, have been built of it; its durability is equally attested by the great masses of the pyramids of Egypt, and by the works of the elder sculptors of that celebrated country, some of which have lately been brought into England, and which are wholly uninjured by time.

In touching upon this subject, I cannot avoid expressing a deep regret, that we have so few of these memorials in this great country. Yet our materials are copious. Our harvests of glory are as rich, nay, even more abundant, than those of the great elder nations. Why should the spirit be wanting, by which they are to be gathered in and made permanent? We have had philosophers who are the glory of the whole human race; heroes and statesmen who are the rivals of the illustrious of Athens and of Rome. Yet this metropolis offers no durable tribute of respect to our science, our naval or military glory, and in a thousand years, though there may be a new and more magnificent city on the banks of the Thames, yet there will scarcely be a wall of what we now behold standing; nothing to speak to posterity of what we are in these memorable times; in philosophy the guides, in literature the instructors, and in politics the assertors of the independence of Europe. Nor would such works be devoid of immediate utility,

and beneficial effect. A few columns raised to the illustrious dead,—a few laboratories or museums devoted to the memory of great men, and to the use of students would rise as landmarks of fame, would continually excite to excellence. No motive of exertion is so strong as that founded upon the sympathy of the good and the wise, — no reward so sweet as that of being held up to public admiration as a benefactor of the species, — no glory so pure, so calculated to awaken great minds as that of immortality.

Micaceous schist is a rock congenerous to granite, but it contains only two of its elements, mica and quartz; and these are usually arranged in layers, so that its appearance is similar to gneiss. It derives its name from its glittering appearance.

Micaceous schist may be distinguished from all other rocks by the disposition of its strata, which are usually arranged in curved layers. Its appearance is brilliant and splendid, and even when in large masses it presents a lustre scarcely inferior to that of the metals.

The aspect of micaceous schist, and the nature of the curvature of its layers is expressed in this sketch.

In the scene itself* the effect is wonderfully beautiful and singular, the fantastical curves of the strata appear reflected on the wave. In some masses the mica is white, and in others yellow; they are contrasted like silver and gold, and the similarity of appearance is so great as often to induce the ignorant to suppose that it contains these precious metals.

Sienite occurs much less frequently than either granite or gneiss. It derives its name from Sienna in Egypt; it consists of three elements, hornblende, quartz and feldspar, and its characteristic element is hornblende.

* [Loch Katerine ?]

Sienite sometimes occurs in regular strata parallel to the horizon, but it is generally found composed of small irregular pointed blocks; its colour is generally black, grey, or olive green.

In this sketch stratified sienite is represented.

Sienite is seldom a beautiful rock, but in this case in the real scene, by its dark colour, and its regular line, it forms a striking object of contrast with the brilliant and irregular schist, and in nature, though not in this species of art, the whole group is harmonious.

Serpentine is a rock which has been generally considered as simple and uncrystallized in its nature; but from a number of observations which I have been able to make, I am induced to believe that the true primitive serpentine is in all cases a compound aggregate, and as to its essential parts, like all other primitive rocks, composed of crystals.

The crystals belonging to serpentine are talc, feldspar, and schiller spar, and its characteristic substance is schiller spar.

In all serpentines, crystals of talc or of schiller spar may be easily discovered by the magnifying glass, and the crystallized texture appears distinct. And in most cases this is evident to the naked eye. The variety of colours which serpentine exhibits, and from which it derives its name, and its lustre, and soapy feel, are principally owing to the veins of steatite it contains, which are often green, red, white, and of the most brilliant tints; but these are veins of after formation, and most probably derive their existence from the decomposition of a part of the rock.

I have traced, near Coverac on the coast of Cornwall, the transitions of serpentine from the most coarse-

grained, composed of large crystals of talc, schiller spar and feldspar, to the finest and most compact. Whoever examines that spot, will, I conceive, scarcely entertain a doubt of the general fact of its composition.

Serpentine at a considerable distance is easily distinguished by its aspect from other rocks. It occurs in masses which generally approach to the square figure, and often presents a number of small and irregular chasms.

Serpentine is one of the primitive rocks which contains the greatest number of perforations and caves. And when it occurs upon a great scale its appearances are in the highest degree picturesque.

In the large masses of serpentine as they exist in nature, nothing can exceed the variety of the colours, and the smoothness and polish of the surface. Red, dark green, brown, and yellow, all appear, sometimes distinct, and sometimes softening into each other; the white foam of the wave becomes a cause of contrast. And if granite is the most sublime of the primitive rocks in its aspect, serpentine may be said to possess the highest character of beauty.

It was once doubted whether any limestone or marble existed free from shells. But the most accurate researches have lately demonstrated that there are undoubted primary rocks of this substance found contiguous to the other primitive rocks.

Primary marble is known from other marbles by the distinct crystallizations of its texture, which appear like those of sugar. It is usually composed of one species of crystals, calcareous spar.

The colours of marble are various; its aspect is peculiar and marked; its outline is very soft, and composed of curved lines; its strata are often parallel to the hori-

zon, and its surface, where it is not broken by veins, is exceedingly smooth and equable.

Porphyry differs from all the other primitive rocks, by containing large crystals in a mass either uniform or composed of smaller crystals. The crystals are feldspar, sometimes with quartz. The base is sometimes minute crystals of feldspar, and sometimes compact feldspar, and now and then hornstone. Porphyry is found of various colours, but the most common are yellow or red. The red porphyry is the most beautiful, and the colour of the crystals being lighter than that of the base, it presents, when polished, a surface diversified by oblong or rhomboidal forms. Many of the great pillars of the ancients are made of porphyry, and it is an excellent stone for architectural purposes.

The aspect presented by porphyry is, in some measure, similar to that of granite; but the blocks are smaller, and the surface much smoother. The masses of porphyry are rarely extensive, and hence insulated rocks or cliffs of it seldom present much grandeur of form, or variety of appearance; but when blended with wood, or river scenery, as it is in several valleys near Ben Nevis, the appearance is exceedingly beautiful.

This sketch represents one of these valleys, that of the Awe.

I have rested for many hours upon the rock represented here, and I have scarcely ever witnessed a more impressive scene. The waters of the majestic Awe, the distant sources of which are amidst mountains abounding in morasses, appear of a bright olive tint, when seen by transmitted light. The white surge of the torrent, the green of the neighbouring woods, the grey of the distant mountains, and the bright red of the porphyry, the masses of which are upon a greater scale than usual,

more distinct, and more majestic, form an assemblage of objects too brilliant for the geologist to dwell upon, and fitted only for the poet, or the painter.

I have described as you have perceived only six orders of primitive rocks, and adhering to the strict sense of the definition, these appear to me to contain all the bodies that truly occur as great primitive masses in nature.*

In the Wernerian arrangement, argillaceous and silicious schistus are considered as belonging to this class of bodies; but in all the varieties of these substances that I have been able to examine, there appeared evident marks of some of their parts having belonged to a prior order of rocks. I have several times investigated, with considerable attention, the great silicious and argillaceous schist beds of Wales, Ireland, Cumberland, and Cornwall, and I have observed fragments of destroyed primary rocks in all of them, and in those of Wales I have in several instances found shells. They are all analogous to each other, and I have compared them with the argillaceous and silicious schists called primitive in a collection made by Werner,—his Thonschiefer, Kieselschiefer; and I find them identical in species.

Werner has adopted an order which he calls Topaz Rock; but this substance has as yet been found only in one place, and consequently ought not to enter into a general arrangement; its mass is likewise very small, and when minutely investigated, I have very little doubt but that it will be found to be a parasitical substance, or disposed in veins.

Large veins of quartz, and likewise of hornblende and of compact feldspar, often occur in the chasms of

* [In pencil the author added a seventh,—quartz rock.]

primitive rocks; and these substances are sometimes found in small insulated masses, which probably originally formed parts of veins, but they never I believe constitute districts, or great and extensive rocky strata, and it is these alone which have been the objects of our present view.

The primary rocks, in their natural arrangement, have certain relations to each other, which, though not invariable, yet are sufficiently constant in all common cases.

Granite, the highest and deepest of rocks, appears to form the great foundations of the surface; and it is usually covered, when not in elevated peaks, by gneiss, micaceous schist, or sienite.

Serpentine and marble are seldom found in very deep, or very elevated regions; they occupy the middle stations of mountain chains, and are much oftener found upon micaceous schist than on granite rocks.

Porphyry is generally associated with granite, and is often immediately incumbent upon it; but it sometimes constitutes considerably elevated mountains, as is the case in the American Andes, and in the Sicilian Alps.

In the grand English association of primitive rocks, beginning at Dartmoor in Devonshire, and ending at the Land's End, the granite forms the great middle range of the mountains; the micaceous schist declines towards the southern and the northern shores. The Lizard is composed of serpentine and sienite upon micaceous schist. The small quantity of marble that exists is found upon the micaceous schist in the rocks of Padstow; and the porphyry in a number of spots appears incumbent upon the granite.

In Wales there is no truly primitive chain. In Ireland the great central association in Wicklow, Dublin, and Kildare, is principally composed of granite and

micaceous schist. Porphyry is seldom found; there is no serpentine in this district, and very little sienite, except at the bottom of the northern mountains. Some quarries of primitive marble occur at the eastern foot of the granite mountains of Dublin.

Amongst the Scotch mountains, Ben Nevis, the highest in the island, is nearly 4,500 feet above the level of the sea; it is composed of granite, micaceous schist, and gneiss, and most of the other great mountains are similarly constituted. Porphyry, sienite, and marble occur, forming as it were smaller chains upon them, and the serpentine is principally limited to a spot on the west coast near Portsoy, and a spot on the coast of Ayr.

Identical or very similar relations exist in the more extensive mountain chains belonging to great continents, (as may be learned from the writings of de Saussure, de Luc, Pallas, Born, Werner, Humboldt, and Raymond), in the Swiss Alps, the Pyrenees, the Saxon rocks, and the mountains of America; and from the conformity of most of the later observations, there seems great reason to believe that the more minutely inquiries are carried on, the more the earth is explored, the greater uniformity and distinctness will be observed in the relationship of the positions of rocks, and in their general arrangement.

The chains of primary rocks, often extending for many hundred miles, in their geographical position, are of considerable importance in preserving the harmony of the great series of natural events.

The heat of the atmosphere is derived from the agency of the rays of the sun on the surface of the earth, and it diminishes in proportion to the height; so that in all seasons, and in all climates, at two or three miles high,

the air is intensely cold. Mountains necessarily partake of the temperature of the regions of the atmosphere into which they are elevated; and in all altitudes when above 15,000 feet high, they are covered with constant snow. And the limit of the point of congelation diminishes, in a regular progression, from the equator towards the poles; so that in Britain it is about 5,000 feet high, Ben Nevis, the great mountain of Scotland, being nearly within the limit of perpetual snow. The tendency of mountains is necessarily to diminish the heat of the countries in which they exist, and they are found most elevated, and upon the greatest scale, in those regions, in which such effects must be most beneficial. The highest mountains of the world are the Andes of South America,* and the most elevated country, the plains of Quito beneath them; and they are situated under the Equator, and by the cooling influence of the central elevated land, a great extent of continent is preserved temperate and habitable, which must otherwise have been a burning desert. The breeze that passes from the high mountains carries with it coolness and moisture, and takes the place of the heated and lighter air and prevents its stagnation, and nourishes and refreshes the vegetable and animal creation. In Asia the great mountain chain that crosses Thibet, and that extends into Persia and Tartary, has a similar effect in diminishing temperature, and it is the northern breeze, that sweeps over this chain, which renders the heat of the midland parts of Hindostan supportable in the summer months. In Africa, except where the influence of the mountains is perceived, the country is little habitable. The effect of the Andes of Abyssinia

* [When this lecture was delivered the greater elevation of the Himalaya had not been ascertained or even conjectured.]

is felt in Egypt; and Atlas and the Mountains of the Moon are scarcely inferior in height to the Cordilleras. In Europe, likewise, the Alps and the Pyrenees are of the greatest importance with regard to temperature; but the greatest elevations are near the Equator, and the heights of mountains diminish towards the poles.

The general agency of mountains is that of cooling: but they likewise often influence the course of the winds, so as to protect the lower regions from their effects. In Britain, for instance, the principal mountains occur in the north and north-east, and our hottest winds in summer, and our coldest winds in winter, blow from these quarters, so that their situation is well adapted to diminish the heat in one case, and to break the force of the cold blast in the other case.

It is a general fact of considerable importance, that when a coast is mountainous and elevated, a correspondent depth of the sea occurs close to the land; and, in many cases, this circumstance produces very extensive and beneficial results. On the coast of Norway, for example, there is a great range of mountains, and a great depth of water; and it is owing to this depth of water near the shores, that the northern sea, for twelve degrees of latitude, is preserved open, and free from ice in the coldest winter.

Sea-water is specifically heavier at a few degrees above the freezing point, than at the freezing point, and consequently, in a large volume of water, no ice can be formed, till throughout its whole depth it is cooled nearly to the point of congelation.

In the high northern ocean, a winter does not afford sufficient time for the cooling of the whole mass; but in the shallows off the coast of Denmark, and of Holland,

though in a much lower latitude, the sea is soon closed by the first severe cold.

Were the high north seas frozen, our winters would be infinitely more severe than they are at present, and our summers much more wet and disagreeable. And there is great reason to believe, that our general temperature, instead of being tolerably mild, would approach very near to that of Kamtschatka, which is situated under the same degree of latitude, and which owes its coldness, in great part, to the vicinity of the icy sea.

Hills and mountains are the great sources of rivers and springs. In consequence of their low temperature, they are constantly precipitating moisture from the air. And from the clouds which form on them, or from the thawing of snow, there is a continued supply of water, which is carried by gravitation from the loftiest summits to the lowest levels. Springs unite to form brooks,—brooks to produce rivers, and torrents which, at their origin, flowed only over bare rocks, watered only the moss, the lichen, or the solitary tree, become majestic streams in their progress, and produce the fertility of the valley, and the verdure of the cultivated plain.

The primitive rocks form the unalterable foundations of the earth, and even those strata of them which have been buried deep, which have no elevation, act by preserving the consistency of the surface, and prevent water, and the matter capable of being organized, from penetrating to too great a depth, where they would be lost and useless to the living world.

By the irregularities in the exterior of the globe, the whole quantity of its surface is considerably increased, and those parts which are not inhabited by living beings are, at least, in some measure, subservient to their existence, and connected with their enjoyments.

The different primary rocks, as we have seen, are composed, at least as far as regards their essential parts, of a very few crystallized substances. Quartz, feldspar, mica, schorl, hornblende, schiller spar, talc, and calcareous spar, may be said, in their different forms, to complete the catalogue. This is a striking proof of the resources of nature. But there is one still more impressive in the circumstance, that these mechanical elements of rocks are themselves chemically composed of a very small number of undecompounded substances. By the methods of the chemist, the hardest stones are capable of being brought into solution, and their different elementary materials separated from each other, and obtained in their pure forms. Refined analysis, completed by the labour of ingenious philosophers of the present day, have shewn that the great ingredients which constitute the primitive rocks are four earths, silex, alumine, lime, magnesia, fixed alkalies, and the oxide of iron; and these are usually all combined in different proportions in the various aggregated parts. Thus quartz consists principally of silicious earth, with very minute portions of alumine, lime, and oxide of iron. Calcareous spar contains chiefly lime and elastic fluid; but generally a perceptible portion of some or all of the other ingredients. Feldspar contains all the five substances in different quantities, and united to fixed alkali; and mica, hornblende and talc, contain, as individuals, all the five elements. But silex is the most abundant in mica, alumine in talc, and oxide of iron in hornblende. But these earths and alkalies are themselves compounds and analagous in constitution. For they consist of metals united to oxygen, one of the constituents of the atmosphere. This I have endeavoured to shew, by a copious collection

of experiments and observations in the Chemical Lectures.

The powers of decomposition, in the possession of chemistry, are very extensive, but those of composition are extremely limited. We have attained the power of extracting metals from the alkalies and earths, and these metals can again be restored to their primary state, but as yet there have been no successful imitations of the crystallized arrangements belonging to nature.

I stated, in the introductory Lecture, that the formation of the primary rocks may be hypothetically explained, by conceiving the central part of the globe, principally constituted by the metals of the earths, and that rocks and strata would result from the action of air and water upon these highly inflammable materials; but still, even on this view, another hypothesis is necessary for the continued renovation of the system.

The want of coaly matter in the primary rocks, is an argument against their having been parts of an order similar to that now in existence. For coaly matter is an almost indestructible substance, and abounds in every part of our existing continents and islands; and is discovered in large quantities in all the rocks of secondary formation.

In all systems for explaining the formation of primary rocks, a fluid state, either from igneous or aqueous fusion, is assumed; but it is not explained why different crystals should separate in the same mass. And this inquiry can be enlightened by no other means than the exaltation of our chemical powers.

Whenever natural causes can be fairly investigated, it is the business of philosophy to endeavour to trace them; and no objects of research, however hidden, connected with the discovery, ought to be neglected, provided in-

struments of investigation can be applied to them—provided they are capable of being elucidated by analogical inferences from known facts. But in cases where there are no histories to guide us, no distinct reasonings to assist us, and no experiments to enlighten us, there the human powers must be uselessly applied, and all the efforts of ingenuity wholly wasted. The discovery of the limits between what is capable of being known, and what must be for ever concealed from us, with regard to the theory of the earth, is perhaps not very distant. In every view of the subject, some point must be taken from which to begin; some primary state of things, or some part of an order of revolution; and where no change is to be perceived, there it seems reasonable to suspend our inquiries, and to consider the facts as ultimate. In this case, there is some foundation for gradually creating a theory; in the other, there is no basis to begin with. In the operations of nature, there is a continued succession, a destruction and renovation of forms. But our view, and our period of existence, limit us to the few objects surrounding us. Suns and worlds may be created, and may decay, by uniform laws, ordained by infinite wisdom; and our earth, as a part of the planetary system, may participate in a new order. But these objects are far beyond mortal ken; the imagination soars towards them in vain; its efforts are idle and unavailing; its strength is wasted in dreams.

In the common course of natural events, there is solution, and decomposition, and consolidation, and the agency of water and of fire; but nothing results analagous to the primary bodies. Calcareous concretions are formed, rocks are destroyed by the agency of air, and new masses regenerated: but they bear the stamp of their origin.

Nature acts by rivers and by seas; but no substances, like the primary substances, are ever produced in them. She pours forth from the volcano, the fused materials of strata: but as far as they have been examined, they cool into amorphous masses, or into single crystalline forms. She raises islands from the sea, by submarine explosions; but they are found to present either lava or sand, and unaltered rocks.

When Newton applied his unparalleled sagacity to the development of the order of the planetary system, he did not begin his researches by endeavouring to discover how they received their present forms, or how they were endowed with the power of motion. These questions he left untouched. He was contented with the arrangement of known phenomena, and the explanation of nature by analogy, compared with facts. And in consequence he had the glory of unfolding the most sublime laws of the system, attained by human intelligence. Such an example, may be successfully imitated in all researches.

[ON THE PHENOMENA AND CAUSES OF VOLCANOES.]*

Most of the changes that now take place in the solid parts of the earth, except those produced by volcanic fires, were considered in the last lecture. I shall now ask permission to direct your attention to this part of the subject, which demands an extensive discussion.

To persons who inhabit countries happily not liable to these grand and awful operations, they may appear rather as *accidents* than as essential events in the order of things; but their extent, their constancy, and the ultimate tendency of their effects, lead to a very different conclusion; and irresistibly prove to us their importance, their efficacy, and even their utility in the great series of the phenomena of nature.

Volcanic fires have operated to a great extent in all quarters of the globe, and they appear to have occurred in the earliest ages of which we have any authentic records. Pindar, who lived nearly five hundred years before the Christian era, mentions the eruptions of Etna, and blending the description of this great natural event with poetic fable, he attributes the effect to Typheus, who after being defeated by Jupiter, in the wars of the gods and Titans, was supposed in the ancient mythology to have been buried under Sicily. The passage is one of the finest in the Odes; I shall read a few lines of it in West's translation:—

* [From a Geological Lecture, the sixth of the course for 1811; developing the early views of the author, respecting the cause of volcanic action, which he afterwards relinquished.]

> "Now under sulphurous Cuma's sea-bound coast
> And vast Sicilia, lies his shaggy breast
> By snowy Etna nurse of endless frost,
> The eternal prop of heaven, for ever prest;
> Forth from whose nitrous caverns issuing rise
> Pure liquid fountains of tempestuous fire,
> And veil in ruddy mists the noonday skies
> Whilst clothed in smoke the eddying flames aspire."

In South America, in the Cordilleras, the highest mountain chain belonging to the earth, a number of volcanoes now exist in a state of activity. In Japan, in Kamtschatka, and in Iceland, a great part of the surface has been formed or modified by the agency of volcanic fires. In Sicily, and in a number of the islands of the Mediterranean sea, their effects are equally visible.

A terrible eruption of Etna is recorded by Thucydides to have taken place 476 years before Christ, and long anterior to this time, "its summit crowned with snows emitting flame," had been celebrated by the Greek poets.

In Italy and the South of France a considerable portion of the country exhibits proofs of ancient volcanoes. Vesuvius, as we learn from Diodorus Siculus and Strabo, was overspread with ashes before the first recorded eruption in the 79th year after the Christian era. Pompeii, a city buried by that event, and since partly uncovered, is found built of lava; even Rome itself, proudly called by its ancient inhabitants the *Eternal City*, (as would appear from the testimony of an excellent mineralogist,) is founded upon the ruins of an extinguished volcano; and many of the beautiful hills and valleys of Auvergne and the Vivarais are said to owe their rich and abundant soils to decomposing lava.

The subject is extensive and sublime; it can hardly fail to excite curiosity in all minds attached to the knowledge of nature, and it possesses numerous rela-

tions to the general theory of the earth; it affords the only known facts of the agency of heat upon rocks that occur on a great scale; it exhibits to us the grandest of the operations of natural chemistry, and it offers a rich, and as yet almost an untouched field of discovery.

Till within the last few years volcanoes had been merely a matter of wonder and vague narration, and had little occupied the attention of philosophical persons. Sir William Hamilton may be said to have been the first accurate observer of the phenomena. His magnificent work on the "Phlegræan fields" is well known; it equally demonstrates the extent of his knowledge, and the refinement of his taste. It affords the true and picturesque characters of a great volcanic region, and the illustrations are the productions of an elegant and acute mind.

The path pointed out by our celebrated countryman was immediately followed by an able philosopher,—by Dolomieu. In his work "sur les Isles Ponces," the most minute observations may be found combined with the most enlarged views, and the author has enlightened his Geological Researches by the assistance of the most refined methods of chemistry known in his time.

The last edition of the Philosophical Travels into Campania, by Scip. Breislac, is likewise an excellent work. The mineralogical details are admirable, the descriptions are animated, and allowed by those who have followed his steps to be peculiarly accurate. To this last book I shall occasionally refer. It is replete with new and useful information.

The work of Dr. Van Troil on Iceland, and the letters published by Sir John Stanley, in the Transactions of the Royal Society of Edinburgh, offer admirable de-

tails on some of the most curious objects of a most interesting volcanic district, and the letters on the hot springs are highly worthy of perusal, not merely on account of the excellent scientific details which they contain, but likewise on account of the elegant and vivid descriptions of some of the most peculiar and magnificent phenomena in nature.

The forms of volcanic mountains, in cases where they have been actually produced or covered by the lava, are usually conical. They are generally more steep and abrupt towards the summit than primary or secondary mountains, and their tops present a pointed and irregular outline.

The rocks that constitute the exterior bases of volcanic mountains, and which have not been altered by fire, differ very much in species in different countries, and their nature is in no way connected with the changes taking place in the interior and lower regions of the district. The seat of volcanic fires is deep in the bosom of the earth, and they have often broken out amidst primary as well as secondary strata. The rocks that appear at the foot of Vesuvius are principally shell-limestone. The foundations of Etna are said to be granite and porphyry; and these substances, according to the reports of Humboldt, constitute the base of the great volcanic chain of the Andes, some of the eminences of which are elevated to the enormous height of four miles above the level of the sea.

The lower regions of volcanic mountains, even when the substratum of the soil is lava, are usually exceedingly fertile, and when a long-continued quiet has prevailed in the interior, vegetation is vigorous upon all parts of the surface that are not raised above the line of perpetual snow. Even in the dreary climate of Kamts-

chatka, the lowlands, in the summer months, are clothed with grass. Soon as the snows have disappeared, the warmth of the sun, acting upon soil produced by decomposed volcanic matter, covers it with verdure; and by far the most fertile parts of this wild and desolate country are those situated in the neighbourhood of subterranean fires.

In mild and temperate climates the fact is still more striking; and Italy affords a number of perfect instances. In the account given of the crater of Vesuvius, by Bracchni, before the eruption of 1631, a time when it had been quiet for a great number of years, the interior of the mountain is described as in the form of the hollow of an inverted cone, covered with luxuriant vegetation, and abounding in majestic trees. And in those places where of late years the fiery flood of lava has boiled up, he describes streams of pure water as flowing down, cooling the air, and affording nourishment to the various tribes of plants that adorn their banks. The height of Etna is about 10,030 feet, and its circumference no more than 40 miles, and yet so fertile are the soils in the lower part of the mountain that the population is immense, and the number of the inhabitants of the district is said to exceed 300,000.

The summits of volcanic hills, when elevated to any considerable height, or after having felt the effects of an eruption, present a striking contrast when examined in the same view with the lower regions. Black, and rugged and barren, if not covered with snow, they bear the evidences of having been changed by the force of fire. Formed of lava and strewed over with scoriæ, or with volcanic dust and sand, they present pictures of which all the features are wild and sublime, and more impressive as they necessarily call up in the mind the

ideas of the great natural events by which they were formed.

Most of the craters, or interior cones of the great volcanic mountains, in their common states emit smoke, or some kind of vapour; and the lava, of which they are composed, is very irregular in its forms, and various in its constitution. Breislac thus describes the crater of Vesuvius, as it appeared in 1800. "The cone," he says, "is cut in an inclined plane, having its direction from north-east to south-west. The circumference of the crater is about 3000 feet. At the bottom is a considerable plain, from which vapours of different degrees of density almost constantly issue, and the sides of it offer the remains of the last lava that issued from it in the eruption of 1794." Dr. Van Troil mentions very similar facts with regard to the different craters of Hecla, in Iceland, which having their exterior covered with snow, constantly emit from their interior vapours insupportably hot, and exhibit walls of lava having the appearance of black glass. But of all the volcanic craters that have been accurately examined, that of Etna is upon the grandest and most magnificent scale. The exterior walls, according to Ferrara, are at least 1800 feet high, and the circumference of their edges cannot be less than a mile and half. The bottom is a horizontal plane, from which constantly issue immense columns of smoke. Spallanzani asserts that he saw in the bottom of the crater, at a time when the smoke was blown off from it, an aperture in which melted lava was in continued motion, but it is generally supposed that he was mistaken.

The general aspect of a volcanic district, even in its most quiet state, must be highly impressive; but when the subterranean fires are displayed in their full energy,

when they burst forth from the interior of the earth, desolating and destroying, then the effect must be beyond all comparison the most awful and the most sublime of the phenomena belonging to our globe.

Multiplied descriptions have been given of the eruptions of volcanoes. Philosophers have detailed them, poets have painted them; but language must necessarily fail when applied to such a purpose; and not even the most perfect delineation of the most perfect master could do justice to a combination of circumstances, in which feeling and hearing and sight are almost equally concerned, in which the earth trembles, in which the continued sound of thunder dwells upon the ear, and in which the eye is constantly dazzled by lightnings flashing in the heavens, and by liquid fire bursting from the earth.

From the most accurate accounts it appears that before any great eruption takes place, the mountain for a considerable time is more than usually tranquil; and one of the most common indications of the approach of the event is a great stillness in the air, and a drying up of the streams in the vicinity. The period of quiet announces the approach of danger; 'tis then that nature seems as if preparing her materials for this terrible operation,—her tranquillity is the forerunner of destruction. Slight tremblings of the earth form the first phenomena in the series. The smoke issuing from the crater increases in quantity, and spreads into the air in the form of an inverted cone. An earthquake usually announces the first appearance of flame, and the melted lava is poured forth amidst noises more terrible and louder than thunder, whilst the ground is agitated by a series of continued shocks. Whether the fire breaks forth amidst the snows of Iceland, or the fertile hills of

Italy, it is announced by the same indications, accompanied by the same effects, and has the same termination.

In cases when phenomena are so similar the same reasonings may be applied to their causes. And the immediate agents in volcanic eruptions are in all cases evident. The trembling of the earth, the noise in the crater, and the loud explosions are all evidently owing to the energy of elastic vapours, and it is by these that the stones and ashes are raised, the ground opened, and the torrent of lava poured forth.

This explanation is so evident that it did not escape the genius of the ancients. Lucretius has given it in his 6th book in some lines that may be thus translated.

> "In Etna's caves, expanded by her fires,
> With mighty force the imprison'd air aspires,
> And whilst escaping from the vast profound,
> Shakes the firm earth, and scatters rocks around,
> O'er the green fields and fertile vineyards pours
> Ashes and sand in desolating showers."

The elastic matter given off in volcanic eruptions is principally steam mixed with inflammable air,* with carbonic acid, and some other acid vapours. Sulphur likewise is raised in the volatile state, for it condenses sometimes on the sides of the crater; and the torrents of rain which follow eruptions, and which are often more destructive to the labours of the husbandman, and more extensive in their desolating effects than fire, are owing to the condensation of aqueous vapour.

Sometimes primary or secondary rocks are thrown out by the force of explosions unaltered by fire; but the great products are matters in igneous fusion, principally consisting of the earths in intimate combination with oxide of iron and alkali, and mixed with more or less of the unaltered materials of the mountain. It is

* [The inflammable air is very questionable.]

from the products, and the agencies of volcanic fires alone that we can reason concerning their causes. A number of difficulties undoubtedly oppose themselves to the investigation. The substances concerned are hidden deep in the bosom of the earth, and it is scarcely possible for us to contemplate them in their active states, even their *effects* can only be examined at a distance; and from their awful nature it is scarcely possible for the most philosophical and courageous mind to examine them with coolness and precision.

These circumstances have induced many philosophers to give up the inquiry as hopeless; but we are possessed, by the discoveries of modern chemistry, of many analogies on the subject, and as far as these can be our guides it is certainly fair to pursue the investigation.

The nature of atmospherical electricity — of lightning, was much less known in the beginning of the last century than the causes of volcanic fires are now, — and where analogy is capable of being applied, discovery should not be despaired of. I do not mean to insinuate that we shall probably gain the same power of averting the effects of earthquakes and volcanoes as we have done those of thunder clouds; but at least as a matter of curiosity the inquiry is worthy of pursuit, and it is connected with objects so grand and magnificent as necessarily to excite the active imagination.

One of the earliest hypothesis formed to account for the origin of volcanoes is, that a permanent central fire occupies the interior of the earth; and that the apertures of burning mountains are the places by which it finds vent, by which it is sometimes discharged into the atmosphere.

This notion would be admirable from its simplicity, if it did not interfere with all our established ideas, and

all known facts concerning the nature and communication of heat. Heat in all its states is capable of being transferred from body to body, and if the interior of the globe had been from all time in a state of ignition, the effects must have been long ago communicated to the surface, which would have exhibited not a few widely scattered volcanoes, but one glowing and burning mass.

The philosophers who have defended this opinion have gone further even than the ancient priests of Vesta, who, though they attributed a divine nature to fire, yet knew that without fuel the flame on their altars would be soon extinct.*

We can reason only by induction or analogy from facts that we are acquainted with, and all the common phenomena of fire occurring on the surface of the globe are connected with chemical changes, with the mutual agencies of different substances on each other; and the quiet of a volcanic mountain after eruptions, the cessation and renovation of the effects in the same district, and the different intensity of the effects at different times, all point to chemical changes as the probable cause for these grand occurrences.

But what chemical agencies are capable of producing such effects?

If an operation of combustion has taken place, and I wish to ascertain the causes, I examine the results, and form my conclusions entirely upon their peculiar nature. Here is a vivid combustion. Suppose a white powder is produced; I examine it, and find it phosphoric acid. Of course I conclude that the effect depended upon phosphorus.

(INSTANCE.
Combustion of Phosphorus in Oxygen.)

* [Latterly it was this hypothesis which he most approved of.]

What are the results of a volcanic eruption? Lava, principally the earths and alkalies in a state of ignition, aqueous vapour, inflammable gas, which burns as it rises. But from what can these products have arisen? I have mentioned the experiments which show that the earths and alkalies are capable of being reduced into metals, which are amongst the most combustible bodies in nature, so that they even burn in contact with water.

And if it be supposed that the interior of the earth contains alloys of these metals with common metals, a supposition which is warranted by the observations of Dr. Maskelyne, and Mr. Cavendish on the mean density of the earth, the phenomena of volcanic fires might be easily explained. Water it seems is always connected with the effect. Most of the great volcanoes are near the sea, or extensive lakes, and aqueous vapour, as I have said, is one of the products, and inflammable air which would result from the decomposition of water by the metals. The elastic substances on such an idea would be such as they are found to be,—the fluid products would be lavas, becoming combinations of the earths and alkalies on cooling.

I showed in the Chemical Lectures an experiment which, on the hypothesis advanced, may be regarded as offering an illustration of a volcanic eruption. I shall repeat it on a larger scale.

(INSTANCE.)

Even this is a very feeble imitation; but in the operations of nature, where immense masses of the metals of the earths may be supposed to exist, and to be acted upon by great bodies of water flowing in from the ocean, the effects would be correspondently grand.

The lava poured forth might cover miles of country. Earthquakes would be felt from the action of the great quantity of inflammable air. Mountains might be raised on the land, and islands elevated in the sea. Electrical changes in most cases precede or are connected with chemical changes, and hence the explosions from the elastic matter, and the fire of combustion would be associated as they are found to be, and their effects enhanced by thunder and lightning.

On the idea of subterranean fire being produced by the action of water and air upon the metals of the earths as I hinted in the Introductory Lecture, a general hypothesis of geology may be founded.

Water and air in certain operations decompose and degrade rocks; but in these operations they may be considered as acting a contrary part, as consolidating and elevating them.

Electricity has been the great agent for producing metals from earths and alkalies, and if it can be supposed that electricity acting under the pressure of the ocean, or in the great subterranean laboratory of the mineral kingdom is capable of separating the inflammable bases of the earths from their oxygen, then there might be assumed a perfect equilibrium, a consistent balance of powers in the system of terrestrial changes, and a completion of that order to which so many other causes (as was stated in the last Lecture) contribute.

The analogy of nature likewise is in favour of such a supposition. Vegetables absorb principles from the atmosphere, which are again evolved into it at the time of their decay. Water carried into the atmosphere gradually returns to the sea, from whence it sprung. In animal bodies, the materials derived from the external

world, after being subservient to life, are again converted into elements, to be prepared for another circulation. And the idea corresponds with the beautiful ancient hieroglyphic representation of nature—the phœnix rising from her ashes.

These views, though analagous to the views of Hooke, and of Hutton, with respect to the future changes of the globe, yet do not necessarily involve the idea that the primary rocks and secondary rocks were formed in consequence of the operation of similar agencies.

As far as lavas have been examined, none of their parts have been found similar to those of primary and secondary rocks. It may be said that the want of the pressure of the ocean, may occasion this difference; but still there is required some experiments or some observations, which will demonstrate that many different crystals may be formed, from the same fused mass by slow cooling.

Sir James Hall, by a series of beautiful experiments, has shown that basalt, and even limestone, after having been fused, will assume a crystalline form, by slow congelation; but in the specimens of re-produced crystalline basalt that I have seen, the crystals were only of one species,—whereas, in the original, they were of two distinct kinds.

Experiments, similar to those of Sir J. Hall, were made by Mr. Gregory Watt. He fused some hundreds weight of basalt; and suffering it to cool in a mass, examined the results by breaking it into pieces. The largest crystals were found in the interior, where the congelation must have been comparatively slow. His paper on this subject, is published in the Transactions of the Royal Society of London, and abounds in acute observations, and sagacious inferences. It was the first

and only geological production of a mind full of talent and enthusiasm for scientific pursuits,—of a mind which promised much for the philosophy of this subject; but death cut off this bloom of promise and hope for the scientific world at the moment when it was brightest. No person attached to truth, can read his paper without a feeling of regret; and I hope I may be excused for the strong expression of this regret,—for whilst I admired him as a philosopher, I loved him as a man. He was the earliest, and one of the dearest, of my scientific friends.

There is, however, still a noble field of experiment in the effects of slowly conducted heat; and the results may be important in their application to the arts, as well as to the solution of the phenomena of geology:—and there cannot be a more noble and delightful study, than the peculiarities of the combinations of nature; nor an art more worthy of being followed, than that by which her resources are imitated.

The volcanic rocks in general, are extremely liable to decompose. They contain alkali, oxide of iron, and calcareous matter; and all the causes described in the last Lecture, operate powerfully upon them. By their decomposition, pozzuolanes, terras's, and fine red and brown soils, are formed.

I mentioned, in the beginning of this Lecture, the fertility of most of the volcanic regions. They sooner become the abode of vegetation than any other rocks; and their efficacy in combining with other causes in increasing the habitable surface of the globe, is consequently distinct.

In the Azores, in the different Asiatic Archipelagoes, Islands have been often raised. That near Santerin, which rose out of the bosom of the sea in 1707, is now

covered in many parts with vegetables. The Lipari Islands were probably all of them elevated by submarine volcanoes. Fertile fields now exist, where before there was a comparatively useless expanse of sea. The evil produced is transient; the good is permanent. The lava which destroyed Herculaneum has been for fifteen centuries a rich and fertile soil. The ashes which buried Pompeii, have rendered a great country continually productive. The destruction is small and partial—the benefit great and general.

In nature, nothing must be judged of in moments, or from its immediate effects. Her operations are in years, and in ages; and the ultimate tendency of them, the preservation of life. It is by events apparently destructive, that her powers are renovated.

[The author's views relative to the combustion of meteoric stones, in traversing our atmosphere, may be deserving of a place here; they are founded on the same hypothesis as the preceding; were advanced in the same course of Lectures; and they happily explain the partial phenomena to which they apply.]

Amongst the various mysterious circumstances connected with the fall of meteoric stones, no one has more perplexed naturalists than their ignition, and apparent combustion in the atmosphere, and the vivid light they emit.

But these phenomena may be easily accounted for on a hypothesis, which flows from the ideas that have just been developed.

The meteoric stones, all of them consist principally of the earths in a loose state of aggregation; and if we suppose that they come into our atmosphere in a metallic state, their combustion would be a necessary effect of their combination with oxygen; and this combustion

would become more vivid, in their descent, in proportion as they passed through a denser air.

All the accounts of the great meteors which have been best observed, are conformable to such a notion; and that which passed over part of North America on the 14th of December, 1807, offered appearances which can hardly be explained on any other hypothesis than that of actual combustion.

It is described by various accurate eye-witnesses as having the appearance of a globe of fire of $\frac{1}{2}$ or $\frac{2}{3}$, the diameter of the full moon; as flashing with vivid light and brisk scintillations, like those of a burning firebrand carried against the wind. It is said that its splendour gradually became fainter and fainter, like that of an ignited cannon-ball cooling in the dark; and that it threw off various stones of considerable size, with loud explosions, some of which were warm, when found.

Here is every phenomenon which might be expected from the inflammation of a large mass in the atmosphere; and the only substances which we can suppose products of combustion, are the earthy materials.

INSTANCE.

Should this hypothesis be admitted, the origin of these bodies, however, will be still as much an enigma as ever. All that is known is, that they do not belong to the system of our earth. They evidently move in curves, like masses endowed with a projectile force, that have travelled in free space. They cannot be formed in the atmosphere; for in this case, their descent would be perpendicular. They seem to be of another world, and mere travellers in this; but from what source they are derived, for what purpose designed, or by what laws they are governed, we shall probably long remain ignorant.

[ON THE CHEMICAL COMPOSITION OF THE ATMOSPHERE.]*

THE former lectures of this course have been devoted to the consideration of those active powers which are the grand secondary causes of the arrangement and changes of the visible universe.

Though the agents are obscure and mysterious, their effects are obvious and distinct. And the history of the phenomena of nature will be more intelligible in consequence of the examination that has been made of those grand sources of her mechanism and her order.

Heat, light, and electricity are substances, the existence of which is *inferred*, rather than positively exhibited—substances, showing their peculiar properties in consequence of the efficacy of scientific methods and instruments; they are rather refined creatures of the intellect, than matters of common sensation.

The objects that are now to occupy our attention, on the contrary, are familiar as general objects of contemplation to all minds. The air, the sea, and the earth,—the great divisions of our globe, in their infinite diversity of forms,—are continually impressed upon the eye, as connected with numerous wants and habits, or infused in the memory as related to various pleasures or pains, or they haunt the imagination as sources of the magnificent and the beautiful. On these points,

* [This lecture on the atmosphere belonged to the course "the Chemistry of Nature," delivered in 1807.]

science will merely confirm or correct common experience,—will give a clearer or more distinct view of a noble prospect,—or point out new uses, beauties, fitnesses and applications of things which have long been the common property of all active understandings.

It is in the atmosphere that we breathe and move; and health and enjoyment, and even life itself immediately depend upon its peculiar constitution. The subject is almost equally connected with the philosophy of chemistry, and with the philosophy of common life.

The variations of heat and cold, the appearances of meteors, of thunder storms, of mists, of rains, of dews, the wonderful varieties of clouds, are all distinct demonstrations of the constant alterations taking place in the aëriform matter above us.

Late discoveries have developed the general causes of these most important effects; the subject is easily made intelligible, and admits of many experimental illustrations.

The air is that invisible substance which we feel when in motion, as wind; which we are capable of confining, of pressing into a smaller space, and of examining by means of the chemical apparatus, under all its different modifications.

Air, though so subtile and moveable a body, is easily shown to have weight. A glass globe containing 100 cubic inches, when exhausted, loses about 31 grains, as was shown in the course of pneumatics, by my friend Mr. Allen; and, in consequence of the elasticity of air, equal volumes taken in free space, weigh less in proportion as the height is greater, so that at 70 miles high, air weighs 300,000 times less (that is, is 300,000 times rarer) than at the surface, and above 45 miles high, it is incapable of exerting

any sensible attractive power on the rays of light, so as to occasion their refraction.

The atmosphere may be considered as a great laboratory of nature, in which a variety of chemical operations are constantly taking place. Though simple and uniform in appearance, it is very compound in its nature; and it will be proper to examine in detail its constituent parts and their especial operations.

The substance which we are most easily able to infer the existence of in air, is moisture, or some matter capable of assuming the state of water.

The rapid formation of a dark cloud after a sultry morning, and the sudden fall of a shower; the deposition of dew on a clear summer's evening when the air is still and transparent, are facts which most distinctly show the production of water from the atmosphere.

When moisture disappears by evaporation, in the process of drying, it becomes elastic and invisible in air; and certain substances are capable of detaching water from the atmosphere, and of rendering it by their chemical attractive powers again a fluid body.

(INSTANCE.
Muriate of Lime.)

The quantity of water in air is proportional to its temperature. Thus, if air which has been fully saturated with moisture at 40° Fahr. has its temperature raised to 80°, it will rapidly take up a new portion; and if water at 100° be cooled to 50°, it will immediately deposit moisture.

(INSTANCE.
Ice in a Bottle.)

It is not easy to ascertain the precise quantity of moisture dissolved in air at different temperatures; but

it seems probable, from various experiments, that at 40° below nought, a given portion of the atmosphere still contains from $\frac{1}{70}$ to $\frac{1}{80}$ of its weight: and, at 80 degrees it contains at least as much as from $\frac{1}{35}$th to $\frac{1}{40}$th.

The general circulation of water in the system of our globe,—its ascent from the sea into the air,—its precipitation in different forms, and its return to its parent source by rivers and springs, will occupy our attention fully in another part of the course. I am now considering this material of the atmosphere only in its elastic state; and in this state, as well as in the fluid form, it is constantly exerting most important functions.

The variations in the proportions of moisture in the air are essential to its distribution over the surface of the earth; and animal and vegetable structures are so constituted as to bear, without injury, all the common states of atmospherical saturation.

The air of the northern climates in winter, which contains perhaps only half the quantity of moisture that it holds dissolved in summer, has no bad effects on the constitution. The Harmattane which blows from the interior of Africa, and which is said to be so dry that it immediately absorbs the moisture of all dead substances, which splits the wood of furniture, and occasions other similar effects, is considered as a healthy wind; and the Sirocco which blows over the sea to Sicily, and which of course must be comparatively moist, is oppressive from its heat, but far from being injurious, though the air probably contains $\frac{1}{30}$ or $\frac{1}{40}$ of its weight of moisture.*

* [The Sirocco is nearly saturated with moisture: a moist thermometer exposed to it, rarely falls more than 5° of Fahrenheit, even when the dry thermometer is at 85°,—at least in Malta and the Ionian islands, where my observations have been made. The Sirocco is a south-east

As the degree of saturation of air with moisture is immediately connected with the state of the weather, many instruments have been proposed, called hygrometers for measuring the degree of saturation. Most of the common hygrometers are founded upon the principle that various bodies have their volumes enlarged by absorbing moisture, such particularly are vegetable filaments and animal substances. In De Saussure's hygrometer, the expansions or contractions of a hair, are made the measures of changes from dry to moist, or from moist to dry. In M. de Luc's, a thin piece of whalebone is employed. A very simple mode of judging of the degree of moisture in air has been proposed by Mr. Dalton. It is by mixing water at the temperature of the atmosphere, and colder water together; and ascertaining by a thermometer at what degree moisture begins to be deposited upon the glass. And in proportion as this temperature is below the temperature of the air, so in proportion is the air dry. The indications by this process, seem to me more susceptible of accuracy than those afforded by the instruments; which are much more affected by particles of water floating in the air as a finely divided mist or vapour, than by the truly elastic water: and there are few cases in which the lower strata of the atmosphere do not contain in some parts such vapours. It is indeed exceedingly probable that the colour of the air depends upon them. The constant changes of temperature must be connected with constant depositions of fluid moisture, which may be so small in quantity as to appear neither as mist nor dew, and which nevertheless may be capable of

wind. The south-west wind at Malta in summer occasionally has the character of the Harmattane; I have witnessed it 105° in the shade, and then the moist thermometer exposed to it fell 34°.]

reflecting light. The atmosphere appears almost white, or of a very light blue, in seasons or in climates where the changes of temperature are most experienced, and where consequently there is the largest proportion of mechanical vapour (if I may be permitted so to call it) in the air. In the tropical and equatorial climates, where the degree is most uniform, the tint of the sky is of the deepest blue. In mountainous districts, likewise, in proportion to the height, the floating moisture diminishes in quantity, and the intensity of the shade increases. On the top of Mount Blanc, where there was little vapour to reflect light, De Saussure states, that in the day, looking steadfastly upon the sky, it appeared of a blue so deep as to be scarcely distinguishable from black; and in a night in these Alpine regions, all colour was lost, and the stars shone with double brilliancy and beauty.

The next elastic constituent of air to be considered is carbonic acid, or the gas anciently called fixed air. This substance is found in a quantity much smaller than the water; and being elastic at all known temperatures, and under all known pressures, its proportions can only be made evident by means of chemical combination.

If lime-water be exposed to air, a thin film soon forms upon it, and this is owing to the absorption of carbonic acid.

(INSTANCE.)

Caustic alkali, by exposure to air, becomes mild from the same cause. And carbonic acid absorbed by these bodies is again detached by means of vinegar, or acetous acid.

(INSTANCE.)

It thus appears as an elastic fluid; sour to the taste, absorbable by water, &c.

(Charcoal and oxygen,—diamond.)

Very different notions have been formed with regard to the quantity of the carbonic acid existing in the air. It has, by some chemists been rated as high as $\frac{1}{100}$ part, and by others as low as $\frac{1}{1400}$ part. From some experiments conducted with much care, it would appear under common circumstances to be about $\frac{1}{800}$ part. I find that the air contained in a globe of the capacity of 408 cubic inches, is sufficient to saturate 250 grains of lime-water, which require about half a grain of carbonic acid; and, from this estimation, Mr. Dalton's is not very remote; he calculates the proportion at $\frac{1}{1000}$. In general the quantity has been considered much too high in consequence of the imperfection of the analytical methods that have been employed. Alkaline solutions have been agitated in long narrow tubes over quicksilver, and the adhesion of the water to the quicksilver, and its disappearance during the process, occasioned an apparent loss greater than was produced by absorption.

The atmosphere at all accessible heights still contains its proportion of this elastic substance. Lime-water, as we are informed by De Saussure, soon exhibited a pellicle, owing to its absorption, upon the top of Mount Blanc; and air brought down from the upper regions of the atmosphere by means of balloons, has been found to contain a similar relative quantity to the air on the surface.*

* [According to M. Theodore de Saussure, the atmosphere contains a little more carbonic acid in summer than in winter; its mean quantity he estimates at 7·13 in volume in 10,000.—Annal. de Chimie et de Physique, tom. ii. and iii. 1816.]

The carbonic acid, though so small a portion of the atmosphere, yet is continually operating in the economy of things; it is absorbed by plants, and it is one of the sources of the charcoal belonging to their constitution. In consequence of its solubility in water, it is carried down from the strata of air in rains, and mists and dews, and its accumulation prevented, and healthy food provided for the vegetable world.

A quantity likewise is renovated equal to that consumed. In processes of common combustion, of fermentation, and of putrefaction, carbonic acid is always generated. And the respiration of animals is a continued source of its production. And it is a beautiful circumstance in physiology, that though carbonic acid, in its pure form, is in the highest degree deleterious to animal life, it becomes perfectly innoxious when mixed with the other elements of air; and it is in this state equally passive with the aqueous vapour.

Air, after being deprived of its carbonic acid, still retains all its essential characters; its most important properties are still the same; the great constituent parts, oxygen and nitrogen, remain, and may be easily separated from each other, and their proportions ascertained.

If a piece of phosphorus be burnt in a confined portion of air, the quantities being properly proportioned, a diminution of about one-fifth of the volume of the air will take place; the phosphorus will acquire weight, and will be converted into an acid. This is from the absorption of the oxygen; the remaining part is the nitrogen.

(INSTANCE.)

All combustible bodies produce a similar effect; but we know of no body capable of absorbing the nitrogen

of air, without affecting the oxygen; but there are certain substances from which oxygen, after absorption, may be again disengaged; such for instance as mercury, which, at a temperature of 600°, combines with this part of air; but at a temperature of 1200° is incapable of remaining in union with it.

(INSTANCE.
Evolution of Oxygen.)

Oxygen thus obtained is found to be an elastic fluid; 100 cubic inches=35 grs.; slightly absorbable by water, and distinguished from all aëriform substances by the manner in which it supports combustion.

(INSTANCE.
Steel Watch-Spring.)

All the phenomena of combustion in the air are owing to this principle, and the discovery of it was perhaps the noblest birth of pneumatic chemistry; for it has created, as it were, a new world, both in facts and in theory.

Oxygen acts the most considerable part in the various changes of the chemical arrangements of the surface of our globe. By means of its combinations, inert matter that has been organized is dissolved, converted into fluids or gases, and rendered again efficient in the processes of nature. The agency of oxygen is the great source of the fermentation and decay of animal and vegetable substances, by which the living world is constantly supplied with elements of nourishment. Oxygen is absorbed in respiration, and is the most essential material agent in the preservation of the functions of life. Were I to breathe this quantity of air for a minute (what is contained in this gasometer), a certain portion

of the oxygen would disappear; and in two minutes, unless there was a fresh supply, life would cease. This principle, absorbed from the air in so many processes, is again supplied from the vegetable kingdom; and plants are, as it were, so many chemical apparatuses for the purification of the atmosphere. They absorb carbonic acid and water, and the decaying and noxious animal and vegetable fluids; they retain the inflammable principles, and convert prejudicial and disgusting materials into forms of beauty, and into substances of use. They evolve the oxygen, and are essential in all respects to the equilibrium of the principles of the air.

Nitrogen, when examined in its pure form, appears similar in all obvious properties to oxygen. It is less heavy; 100 cubic inches = 30 grains; does not support flame; is scarcely absorbable by water. These are almost negative qualities, but they sufficiently characterize it.

(INSTANCE.)

Nitrogen, though existing in air in quantities so much superior to those in which oxygen is found, is a less general chemical agent. It is not present in any native compounds in the mineral kingdom,* and in very small portions in the vegetable world; but it is ennobled by being almost the characteristic principle in animal structures.

It was supposed by Lavoisier, and the earlier experimenters upon respiration, that oxygen alone was absorbed in this process; but Dr. Priestley soon suspected that nitrogen likewise disappeared; and, in 1799, I was able, by decisive experiments, to determine the fact; and I concluded, from processes made in as delicate a

* [Nitre and nitrate of lime may be mentioned as exceptions, considered as salts of spontaneous production.]

manner as I could contrive, that about $4\frac{1}{2}$ oz. of nitrogen were consumed in my own respiration in about twenty-four hours. Analogous results have been gained by M. Pfaff, Dr. Henderson, and other experimenters; and the fact may be regarded as established.

On the ancient notion of respiration, oxygen was considered as the only principle in the atmosphere essential to life, and the nitrogen merely as a diluting substance—a medium for conveying the more important and etherial principle. According to the new elucidations, the nitrogen (as might be expected from the analogy of things) acts a more important part, and is conveyed as an essential material to animal life in its elastic state to the living organs. And the compensation for it, is made in the processes of decomposition and decay. It is continually evolved during the destruction of dead organized matter in its pure form; and, less liable to combination than its kindred element, is immediately disengaged into the atmosphere, and in constant circulation remains the same in essence.

When the beautiful facts of the chemical nature of air were first established, the permanency of the constitution of the atmosphere, and the relative proportions of this gas and of oxygen in different situations, and their connection with salubrity, became objects of anxious inquiry amongst philosophers; and several methods and instruments were contrived for ascertaining the different degrees of purity.

The first was invented by Dr. Priestley.—Errors.

By Volta.—Errors.

Marti.

Berthollet.

Hope.

My own.—Sulphate of iron.

When inaccurate methods were employed, particularly those with nitrous gas, the greater number of philosophers assumed considerable differences in the proportions of oxygen in the air in different places, and under different circumstances; and these differences have been stated as high as from 18 per cent. to 50 of oxygen.

The later and more precise methods have, however, proved that such conclusions are erroneous, and that in places exposed to a free current of air, or to the influence of the winds, there is never any more difference than could be well expected, from the slight difference in the methods of operation. For the last six years, in operations performed with the greatest care, I have found 21 per cent. in volume the standard. M. Berthollet, and some of our own chemists, made it a little higher; but in a report, published in the beginning of last year, in the Annales de Chimie, I find, that after a minute examination by a Committee of the French Institute, these gentlemen have made their estimations conformable to those which I had ventured to adopt. That there is no periodical change in the constitution of the atmosphere, connected with the changes of season, seems clear from the general series of the experiments that have been made; and, fortunately, we have a term of comparison of twenty-four years' duration in the beautiful and minute processes of Mr. Cavendish on Eudiometry, published in the Phil. Trans. 1783. That gentleman for many months examined the air in London and Kensington with different winds, and at different pressures and temperatures, and he had an uniform result, the proportion being always about one-fifth; so that we may be confident that in twenty-four years there is no distinguishable variation.

I hope it will not be conceived that I mean to apply this conclusion, as to the uniformity of the constitution of air, to close rooms, or to confined places, where there is no free circulation. I must not be mentioned as an authority for the salubrity of a crowded mid-night ball-room, or the press of a "*rout*." Where many candles and lamps are burnt,—where a great number of persons respire the same air, it is scarcely possible, unless all the doors and windows are thrown open, to gain a sufficient supply of the pure atmospheric fluid to make up for the consumption. I have two or three times examined the air of very crowded and oppressive rooms, and in one instance I found as little as seventeen per cent. oxygen, and three per cent. of carbonic acid. In May last, I collected air in different parts of Drury-lane Theatre on a crowded night, by emptying small bottles filled with water. In the Pit, at nine o'clock, there were 19 of oxygen, and $1\frac{1}{2}$ of carbonic acid. In the second row of Boxes as soon after as the process could be conducted, there was a little more than these proportions, but no great difference. But in the highest tier the impurity was greater; there were only 18 of oxygen, and as much as $2\frac{1}{4}$ per cent. of carbonic acid.

The deficiency of oxygen, in situations in common life, is seldom, however, a cause of unhealthiness; and more serious evils are produced by the vapours and effluvia which are suspended in the atmosphere in the solid or fluid state, — vapours from putrifying animal matter, — from decaying vegetables and the products of combustion and various processes of decomposition. The great reason of the superior salubrity of a country atmosphere is not in the difference of the quantity of oxygen; but in the circumstance of the purity of the air from noxious impregnations. The air in the streets

of London is continually conveying to our lungs, parts of whatever in so great a city is capable of very minute division either by chemical or mechanical means. The fogs which we experience are principally water thrown down by cooling from the upper regions of the air; but they often carry with them in the night, the smoke, the soot and the various effluvia which have been raised during the day; and we sometimes breathe a vapour, which before had passed through our chimneys.

When the different nature of the substances composing air and their different specific gravities are examined, we are necessarily led to an investigation of the causes that produce their accurate union. It is evident that they are prevented by some powerful means from being arranged by gravitation, and the investigation of those means is one of great interest, for it is connected with a most important part of the order in the economy of nature.

Scheele, the first analyst of the atmosphere, conceived that the uniformity of its composition was owing to chemical affinity; and this opinion was adopted by Humboldt, Morozzo and Berthollet, and has been advanced in the last edition of Dr. Thomson's Chemistry.*

Dr. Thomson has founded some of his arguments upon experiments that I made on the gases in 1800, which proved that a gas precisely the same as atmospheric air was evolved in some instances of decomposition. I confess, from the first examination of the facts, I was myself induced to lean towards the idea of a chemical combination between the oxygen and nitrogen; but later and more mature observations have altered my notions on the subject.

* [In the third edition; since relinquished.]

It was supposed at that time that the specific gravity of atmospherical air was not a mean between the specific gravities of the substances composing it, — which appeared demonstrative of chemical union. But it is now known that this observation was an error founded upon a mistake in the composition of air, which after the authority of Lavoisier, was considered as containing 28 per cent. of oxygen.

When oxygen, nitrogen and carbonic acid gas are mixed together in the due proportions, there is no change of volume, yet they compose an elastic fluid, having all the properties of air. There is no condensation or expansion, when the carbonic acid and the oxygen are separated from the nitrogen of the common atmosphere; yet this ought to happen if there was any chemical union between them.

Distilled water when agitated with air, absorbs more of the oxygen than of the nitrogen, though if these bodies were chemically combined, it is scarcely possible that such an affinity could separate them.

It is of the highest importance in the science of nature, to employ terms with accuracy and consistency, and to make distinctions clear and obvious. The word Chemical Attraction, since its first introduction, has been applied by the most accurate investigators of its laws to that union of substances in which the properties of the individuals are changed, their volumes altered,* and a new body formed. In atmospherical air, no such effects are observed. And to apply this term to signify the cause of the accurate blending of its parts, would be to introduce an inaccuracy of nomenclature which might become a precedent for perplexing, but which could not serve to enlighten the science.

* [To this there are one or two exceptions since discovered.]

A new hypothesis on the uniform constitution of the air, has been lately brought forward by Mr. Dalton. It was published in Nicholson's Journal, for October, 1801, and has been since defended by the author in various papers.

The density of elastic fluids, as I have already mentioned, is proportional to the compressing force: and on this proposition it has been shown, that their particles must repel each other with an energy reciprocally proportional to the distances of their centres.

This law has been always considered as applying universally; but, Mr. Dalton has attempted to show that its operation is limited, and that it governs elastic fluids only composed of the same species of matter. Thus, he supposes, that the particles of the oxygen in air are repulsive to each other, but not to the particles of the nitrogen or carbonic acid; and the same in the other instances; and he conceives that the different gases though they do not repel each other, yet from their state of interfusion still press together upon the smallest body that can be exposed on the surface of the earth.

This idea is certainly very ingenious, and conceived and developed with an acuteness which characterizes all the labours of the same author. It likewise affords a very ready explanation of the phenomena. But there are facts that oppose themselves to it.

Inflammable air and atmospheric air, according to Mr. Dalton, have no repulsion for each other. If therefore we expose a vessel containing hydrogen to the atmosphere, it ought as soon to mix with the air whether it be inverted or on its base; but this certainly is not the case.

(INSTANCE.
Oxygen.—Carbonic acid.)

In relinquishing the hypothesis of chemical combination and of non-repulsion, the only one which it remains for us to adopt is that which assumes, that the different elastic fluids are in a state of mechanical mixture, and that they are preserved in this condition, and prevented from separating by the constant agitations of the atmosphere by winds and currents of air, and other mechanical motions continually taking place.

Were air visible to us, it would appear even in the calmest weather, in a much more continued state of tumult than the ocean exhibits in the strongest tempests. Every change of temperature changes the place of a column of the whole of the atmospherical fluid. Every motion upon the surface of the earth is communicated to the elastic medium in which it occurs. By the influence of the sun and moon, tides must be continually produced in the air, analogous to those occasioned in the sea, — but much more extensive. A number of other circumstances might be adduced. The system of motions is essential to the preservation of life; and, the same wise laws which give to us heat and light, preserve the salubrity and the vivifying principle of the atmosphere. What an impressive series of circumstances!

"By ceaseless motion all that is subsists."

[HISTORICAL SKETCH OF ELECTRICAL DISCOVERY.]*

In a sketch of this kind, and in the time allotted for it, I shall not be expected to produce a minute history of all the various insulated experiments that have been made. My endeavour will be rather to fix your attention upon the leading and grand discoveries which form the epochs of the science. The brilliancy of electrical phenomena, and the facility of producing them, led an immense number of inquirers into this field of research. Many have developed new objects in it, but a very few only have ascertained principles; and in philosophical annals, the fame of subordinate improvers is necessarily absorbed in that of the noble inventors, as in military details the worth of the common soldier, and of the subaltern, is, as it were, swallowed up in the glory of the general.

The first epoch of electrical science must be referred to the time of Gilbert, and his views are developed in the "Treatise de Magnete," published in 1600. The ancients were acquainted with two electrical bodies only —amber, ελεκτρον, which has given the denomination of the science; and lyncurium, which is either the topaz or tourmaline. Gilbert ascertained that a great variety of substances are capable of being excited,—as glass, sealing wax, resins, gums, and most of the earthy and stony bodies: and that their electricity was impaired by moist air and aqueous fluids, but not by oily

* [Part of a Lecture on Electro-Chemical Science, delivered in 1810.]

and resinous substances; and he supposed electrical attraction to be a general property of matter, and thus contrasted with magnetic attraction, which was peculiar to bodies containing iron.

His work is worthy of being studied, and I am surprised that an English edition of it has never been published. Gilbert was a man above his age; in his own times, his philosophy was little attended to; and one reason why it was neglected in later periods, is the singular reproach thrown upon it by the great father of modern experimental philosophy. "Men," (says he, in his book "De Augmentis Scientiarium") "are continually carrying too far their own favourite theories, and endeavouring to accomplish every thing by their own peculiar arts. Thus, Plato has made all philosophy theology; Aristotle, logic; and Proclus, mathematics; following these sciences as their first-born children, and making them their heirs to the exclusion of all others. So the chemists explain all things by the processes of the fire-place and the furnace; and our countryman, Gilbert, has attempted to raise a general system upon the magnet, endeavouring to build a ship out of materials not sufficient to make the rowing pins of a boat." In another place he treats the important electrical facts which Gilbert had discovered, as fables. The illustrious critic of the sciences was occasionally misled by his zeal for the destruction of prejudices and false opinions, and by his contempt for the absurdities of the ancient schools. Anxious to build up his own great edifice with his own materials, and by his own strength, he refused all assistance; and, the founder of a new and grand philosophy, he scorned to blend either the facts or the opinions of others with what he conceived to be peculiarly his own work. Confident of greatness, and looking with a stead-

fast eye towards the creations of his own noble genius, he did not fully see the merit of others; as in the meridian light of our own sun we cannot perceive the stars, which are, nevertheless, the suns of other systems. No one can exceed me in admiration of this great man; and it is with a feeling of humility that I venture to say, that his reproach of Gilbert is unjust. Gilbert undoubtedly considered the earth as endowed with magnetic poles, and this is now acknowledged as a truth. He perfectly and most accurately distinguished between magnetic and electrical attraction; and he supposed, by a singular felicity of induction, and with a kind of prophetic sagacity, that the motions of the heavenly bodies might depend upon a peculiar gravitation or attractive power. He was far from possessing an unwarrantable spirit of generalisation. In his Latin preface, he says, in words which may be thus translated. "My object is to arrange facts, founded on trials of the properties of natural things, and to give to my subject demonstrations similar to those adopted in geometry, which, on the most simple foundation, raises the most magnificent works; which, by a few propositions, founded on the properties of things belonging to the earth, enables the mind to comprehend the structure of the heavens. I renounce all subtleties connected with letters. I depend upon things which may be made evident to the senses, things which may be easily tried; and nothing in this treatise has been done in haste; every experiment has been carefully repeated."*

* [Gilbert not unfrequently breaks out in reprobating the scholastic manner of philosophizing in terms even more severe than Bacon was in the habit of using. Thus he begins his tenth chapter, "Deploranda est humana in rebus naturalibus inscitia, et tamquam in tenebris somniantes excitandi sunt moderni Philosophi, et ad verum usum et tractationem educendi, ab otiosa ex libris quæsita doctrina probabilium rationum

About fifty years after Gilbert, Boyle and Hooke and Otto de Guerike pursued the subject of electricity; and Otto de Guerike erected the first electrical machine, which was a globe of sulphur whirled upon an axis, and rubbed against the hand. Hawksbee, in 1709, substituted globes and cylinders of glass for the globe of sulphur; and has described in the Philosopical Transactions, and in his physico-mechanical experiments, a great number of the luminous phenomena of electricity.

The electrical effects at this time were, however, referred to no general principle, and they were explained by different inquirers in very different manners, and attributed either to rude mechanical causes, or to some occult specific qualities of the different bodies exhibiting them. This, at first view, appears wonderful; for in the beginning of the eighteenth century the

nugamentis et conjecturis tantum suffulta." And, with the same feeling in another place, he justly remarks, "Facile est hominibus ingenio acutis, absque experimentis et usu rerum labi et errari." p. 52. Tractatus, sive Physiologia Nova de Magnete. Sedini, 4to. 1633. And, in a posthumous work, "De Mundo nostro sublunaria Philosophia Nova," in several places he expresses himself no less strongly to the same effect. Thus, at p. 5, speaking of the influence of Aristotle and Galen on the schools, he says, "Tunc omnes in hæc verba jurare oportuit, tunc ad religionis normam docendi et disserendi forma redacta est, et mandatum has etiam juventuti nugas offerre, singulasque bonarum literarum scholas decretum intravit, *ipse dixit*, *Aristoteles dixit*, *Galenus dicit*, exivit discipulus quid dicerit instructus; quid feceret ignorans plane et inscius." And, again, at p. 74, after noticing some of the different definitions and accounts of the elements by the ancient philosophers, he remarks, "Ita varie etiam actum de definitione elementi, non minore contentione quam de elementis ipsis et numero ipsorum; falsæ enim suppositiones infinitas gignunt garrulitates." This work of Gilbert's, which is little known, is a very remarkable one, both in style and matter; and there is a vigour and energy of expression belonging to it very suitable to its originality. Possessed of a more minute and practical knowledge of natural philosophy than Bacon, his opposition to the philosophy of the schools was more searching and particular, and at the time probably little less efficient.]

methods of philosophical research attained their highest degree of perfection, and the public mind, generally speaking, seems to have been in that happy state in which the imagination and activity of youth are, as it were, chastened by the correctness and sagacity of manhood. But the reason seemed to be, that the objects of the philosophy of the Newtonian school absorbed for at least half a century all the attention of scientific men. The grand laws of the system of the universe came upon the understanding with that kind of effect which the new sensations of vision produce on the blind receiving sight. The mathematical theory of philosophy and astronomy, the laws of light, and the motions of the heavenly bodies, were the universal topics of discussion and admiration.

It is not a little remarkable that the first fact communicated by Newton to the Royal Society was an electrical experiment, and that the truth of his statement was doubted by some of the members of that illustrious body. The secretary was ordered to write to him to relate its failure. They were satisfied by the answer, which, however, proved that the young philosopher was offended by their doubts of his accuracy. If they had persisted in a mistake, it is not impossible that a disgust might have been produced fatal to the cause of science, for it was the connection of Newton with the Royal Society which induced him to bring forward and publish his works. Equally distinguished by modesty as by exalted genius, he pursued science, because his spirit was imbued with an ardent love of truth and an insatiable desire of knowledge. His ardour could not have been damped by opposition; but his love of quiet might have led him to avoid controversy. But it is vain to speculate upon what might have taken place. He

was surely destined for the great purpose which he accomplished,—to exhibit the dignity of the human mind; its wonderful resources; to show the magnificence and simplicity of nature.

The second epoch of electrical science cannot fairly be placed further back than 1730, the time in which Stephen Grey and Du Fay commenced their labours. Mr. Grey's papers may be found in the Philosophical Transactions from 1730 to 1740. Grey gave up his whole mind to the inquiry, and pursued it with his whole heart. He multiplied his experiments with indefatigable industry, and, through a period of nine years, his papers occupy a considerable place in the Philosophical Transactions of the Royal Society.

Amidst a great number of unconnected facts and observations, two discoveries of prime importance occur, —the power of electrified bodies to communicate their influence to other bodies, and the distinction between conductors and non-conductors. Mr. Grey discovered the insulating apparatus, and was the first person who rendered metals, water, and the human body electrical by communication with excited instruments. Grey was a great benefactor to the science; but he was more distinguished for liveliness and perseverance of research than for accuracy and strength of thought. His facts are infinitely more valuable than his theories. Having little general knowledge of science, he erred in what may be called the critical philosophy of his subject; and attempted to explain gravitation, and other recondite powers of matter, by delusive electrical experiments. Thus affording an instance of the truth of that capital dogma of Aristotle, that "those who know only one thing find it easy to account for every thing."

Stimulated by the first discoveries of Mr. Grey,

Monsieur Du Fay, intendant of the French king's gardens at Paris, entered on the same plan of investigation, repeated the different experiments made in England, and added to them various new ones connected with brilliant and important results.

M. Du Fay was the first person who distinguished the two electricities under the names of resinous and vitreous, and he ascertained the very considerable principle that "bodies similarly electrified repel each other; but that bodies dissimilarly electrified attract each other." His discoveries are published in eight memoirs, delivered to the Academy of Sciences, and inserted in their History for 1733, 1734,—1737. His writings display a truly philosophical spirit. He has attempted, in all cases, to generalize on the phenomena, and patience and accuracy seem to have equally regulated his practical researches and his speculative views. He refers to the known facts, to a few propositions; and the germ of a good elementary treatise may be found in his papers. He was an acute and sagacious observer, warped by few prejudices, led away by no fancies.

After the researches of Grey and Du Fay, nothing that materially affected the progress of the investigation, was ascertained till 1745, the year of the discovery of the Leyden phial, which may be regarded as constituting the third epoch in the science. This extraordinary apparatus was first employed by the Canon Von Kleist, of Kamin; but a similar combination was soon after invented by Cunæus and Muschenbroeck, of Leyden. Kleist's form of the experiment was a phial held in the hand, having a nail in it; Muschenbroeck's form was a phial half filled with water. Nothing in the history of electricity, is more singular than the first accounts of the electrical shock, as given by these very feeble and

imperfect instruments; and the astonishment of the discoverers seems almost to have deprived them of their reason. Muschenbroeck, in his account of the experiment, written to Reaumur, states, that "the effect from a small glass bowl was so violent, that he lost his breath and his sensation, and was two days before he recovered from the effects of the blow and the terror; and that he would not take a second shock for the whole kingdom of France." It does not require another example to demonstrate how much the imagination and the senses influence each other. Other philosophers, with a much more perfect and more powerful apparatus, repeated the experiment, without any such terrible effects; and referred to the cowardice of the professor, what was only the effect of his surprise.

No single philosophical discovery, ever excited so much popular and scientific attention, as this of the Leyden phial. The apparatus soon became an object of public exhibition; and in the same year in which it was discovered, a number of itinerant experimenters procured a livelihood in different parts of Europe, by travelling from place to place, and showing the experiment. About the middle of the last century, an immense number of facts had been ascertained, and they were constantly accumulating; and some principles had been developed; but a general theory for connecting the insulated observations, and giving them the form of a body of science, was still wanting. The foundations for this theory, were laid by the ingenuity and industry of our countryman, Dr. Watson; the construction of it is owing to the sagacity of Dr. Franklin. Dr. Watson ascertained that a communication with the ground, is necessary for the production of a continued stream of electricity by the machine; and hence he concluded that

there is an afflux of electricity from the conducting bodies to the glass, and from the glass to the prime conductor. This idea was made known early in 1747; and towards the middle of the same year, Dr. Franklin transmitted his first letter on the subject to Mr. Collinson, containing an account of experiments and observations on electricity made at Philadelphia. In this letter, and in several subsequent letters, in a correspondence that continued till 1774, he brought forward those enlightened ideas of the subject, which have been so generally admired, under the name of the Franklinian Theory. Dr. Franklin proved that the conductor in contact with the rubber of the electrical machine had an opposite electricity from that of the great conductor; that the outside and the inside of the Leyden phial, were likewise in opposite states; and that an equilibrium was made by their mutual agency: and he referred all the phenomena to the redundancy or deficiency of a single fluid. The experiments adduced by Dr. Franklin in support of his hypothesis, were most ingeniously contrived and happily executed. A singular felicity of induction guided all his researches, and by very small means he established very grand truths. The style and manner of his publication are almost as worthy of admiration, as the doctrines it contains. He has endeavoured to remove all mystery and obscurity from the subject; he has written equally for the uninitiated and for the philosopher; and he has rendered his details amusing as well as perspicuous—elegant as well as simple. Science appears in his language in a dress wonderfully decorous, the best adapted to display her native loveliness. He has in no case exhibited that false dignity, by which philosophy is kept aloof from common applications, and he has sought rather to make her a useful inmate and

servant in the common habitations of man, than to preserve her merely as an object of admiration in temples and palaces. The theory of negative and positive electricity was soon made by M. Æpinus, of the Academy of Petersburgh, the subject of mathematical illustration; and this profound algebraist has submitted a great variety of the conditions of electrical action to calculation, assuming as his data, an attraction between the electrical fluid and common bodies, and an excess or deficiency of the fluid, or of the matter over which it is diffused.

A more popular, and not less refined view, of the same doctrine, was soon after furnished by Mr. Cavendish, who has combined delicacy of physical experiment, with elucidations derived from the higher branches of mathematical science, and whose researches in electricity have the same exalted character as those in the other departments of natural philosophy.

The magnificent effects produced by the accumulation of electricity by large machines and jars, soon led philosophers to reason from artificial concerning natural processes. Such an influence it was impossible to conceive passive in the external world; and the most striking analogies soon led to the discovery of its most obvious operations. Dr. Stukely and the Abbe Nollet had observed the similarity between the electrical spark and lightning, and the report of thunder; but Dr. Franklin was the first philosopher who conceived the bold idea of bringing lightning from the clouds,—who first imagined that, by pointed conductors, charged electrical clouds might be made harmless, and the matter of the thunderbolt quietly conveyed from the atmosphere to the earth. The simple apparatus of a school-boy's kite, held by means of a silk handkerchief

attached to a hempen string, with a key for a conductor, enabled him, in June, 1752, to verify the grand idea. The practical application soon followed; and, what rarely happens, the same philosopher had the glory of discovering a noble principle in nature, and of making it of public utility.*

The simple path once opened, a great number of philosophers immediately engaged in the inquiry concerning atmospherical electricity, and a general and copious account of their researches may be found in Priestley's history.

Beccaria and Canton determined the influence of charged strata of air in the phenomena of lightning; and the Italian philosopher made a number of applications of theory to the nature of clouds, the affections of the winds, the aurora borealis, and other appearances. Experiments on thunder-storms were pursued by a variety of persons with great zeal, and sometimes with too little caution, when it is considered what an intractable and powerful agent was concerned in the operations. Amidst such a variety of trials in different parts of Europe, only one serious accident happened; and but one victim fell in the dangerous field of research. Professor Rickman, of Petersburgh, was examining the electricity of a thunder-cloud by means of a new instrument, which he called an electrical gnomon; the expe-

* [M. Arago, in his Eloge Historique of Volta, published in the 54th volume of Annales de Chimie et de Physique, gives credit to Dr. Wall in 1708, and to Stephen Grey in 1735, for the earliest conjectures respecting the electrical nature of the phenomena of the thunder storm; but the analogy which these ingenious inquirers hinted at was so vague, that it might almost be considered poetical: the authors themselves attached no importance to it, nor appear to have given it a second thought, and which certainly had been passed over by posterity as trifling had not a kind of importance more than due been given to their expressions by the great discovery of Franklin.]

riment was fatal: a discharge took place with a loud explosion,—and the philosopher fell instantly dead, immortalized as the first and the only martyr to the science.

In 1774, a new electrical inquiry was brought forward by Mr. Walsh. The powers of the torpedo and gymnotus to give shocks, had been long known. This gentleman proved, by the most satisfactory experiments, that the effect was electrical. And Mr. Cavendish contrived to imitate the electricity of these fishes, by a number of Leyden jars, weakly charged. The electrical organs, dissected by the celebrated John Hunter, were found to be composed of columns of muscular and membranous substances, furnished with large nerves; and it seems exceedingly probable that the electricity is excited, as in other cases, by contact, and accumulated by induction.* In presenting the Copley medal to Mr. Walsh, as a testimony of the approbation of the Royal Society of these his discoveries, Sir John Pringle, then President, in the speech made on the occasion, entered into some noble views, in which there are striking hints of later discoveries; and, after stating that there may be still found out new and more powerful modes of exciting electricity, and of submitting bodies to its operation, he concludes, in his usual animated manner: "But whether this will be the individual effect or not, philosophy, by these curious and successful researches, has made a valuable acquisition; since we may be assured that whatever tends to disclose the *causæ rerum*, the secret laws of nature, cannot ultimately fail of subjecting her, more or less, to the uses of life, and of ma-

* [The existence of muscular substance in the electrical organs of the torpedo is more than doubtful; in the first volume of the editor's Physiological and Anatomical Researches, the question is discussed.]

nifesting, more and more, the wisdom and power of the Creator in all his works. This animal served them (meaning the Ancients) for an emblem or hieroglyphic, for a figure of speech, or an allusion of pleasantry,—at best, as a theme for a copy of verses. But the world, rising in years and in wisdom, rejects such trifles. The interpreters of nature, in the adult state of time, make experiments and inductions, distrust their intellects, confide in facts, and in their senses; and by these arts drawing aside the veil of nature, find a mean and grovelling animal armed with lightning—that awful and celestial fire revered by the Ancients as the peculiar attribute of the father of their gods?"

After this period, which may be considered as the fourth epoch of the science, for several years electrical science may be said to have slept, or, at least, not to have been distinguished by any grand advances. This was the great era of chemical discovery, and philosophical minds were fully busied with other important investigations. Electricity seemed as if nearly exhausted as to all sources of grand discovery; and the love of glory, as well as love of novelty, led ardent inquirers into the extensive and uncultivated field of pneumatic research.

Whilst the discoveries concerning the gases were pursued, no other improvements were made in electricity than a few connected with the construction of instruments; and a mere accidental circumstance led to the pursuit of that novel branch of the inquiry, which, for the last eighteen years, has been so wonderfully extended, and elucidated under the name of galvanism. It had long been known, and the then recent discoveries made by Vassali had shown, that common electricity produced contractions in the limbs of animals just de-

prived of life. Galvani, professor of natural philosophy at Bologna, in 1789, happened, in some physiological experiments, to touch the crural nerve of a dead frog with a knife; violent contractions were produced in the leg: he tried other metals with similar effects, and he found combinations of metals much more efficacious than single metals.

The true discovery of Galvani was that of a delicate animal electrometer. The conclusion ought to have been, that combinations of the metals were rendered electrical by contact. But ideas very remote from this were formed by Galvani and his followers. They conceived that the metals were merely conductors of an etherial fluid existing in the animal organs, and that this fluid was the cause of irritable action. Innumerable experiments were made by Humboldt, by Aldini, by Valli, to determine the laws by which it was governed. The highest physiological discoveries were anticipated; the functions of vitality were supposed to be capable of analysis; and a spirit of generalisation was indulged in, romantic, and far removed from that of sound reason and unprejudiced investigation.

The same year that Galvani made his observations, Mr. Bennet showed that the metals gained electrical powers by contact or friction: and he was enabled to determine this by means of an extremely delicate instrument of his own invention, in which gold leaf is exposed to the body examined, and in which, by particular artifices, the electricity is increased.

One of his simplest experiments was to touch a plate of copper with the blade of a knife,—an effect is found to be produced, in a slighter degree, similar to that produced by the friction of sealing-wax. This discovery, which contained the solution of the experiment of Gal-

vani, was published in a distinct treatise, containing many curious electrical experiments in 1789; but it was neglected for ten years, till the singular phenomena, comprehended under the name of galvanism, began to occupy the public attention.

Volta, in opposition to Galvani, and the advocates of the physiological hypothesis, always asserted that these phenomena were merely owing to the electricity of the metals, and made still more decisive experiments than those of Mr. Bennet on the subject; and this illustrious philosopher put the question beyond doubt by the grand invention of the new electrical battery.

This noble invention, in which the powers of the electrical machine, the Leyden phial, and the organ of the gymnotus, are, as it were, combined and concentrated, brought forward in the first year of a new century, forms the fifth, and not the least important, epoch in electrical discovery; and it has the greater merit, as being the result of thought, and not of accident,—as being at once a demonstration of the principle of the author, and a novel and astonishing combination.

As it is to Volta that we owe the great progression in the science, it is wholly inconsistent with the feeling of justice that the name of Galvani should be associated with his discoveries. Galvanism and galvanic batteries will, I trust, soon become obsolete terms; and voltaic electricity and voltaic batteries take their place. Let honour be given where honour is due, but let not the new and magnificent facts belonging to the novel discoveries be associated with a name to which they bear no relation. Let not the accidental discoverer of an insulated phenomenon, which he was unable to explain, be placed before a philosopher, whose inventions were the result of combination, and whose views have uni-

formly been as sagacious as his experiments are accurate.

Solids were, till the time of Volta, supposed to be the only substances which could be made electrical, or, as it was usually called, excited; but Volta showed that fluids are possessed of this property. One of his experiments was to fill a cup of silver with a solution of liver of sulphur; a leg of a frog made to touch both the silver and the solution undergoes violent contraction.

Even elastic fluids,—air, and probably all the different gases,—are capable of exhibiting electrical effects. Thus, a strong stream of air forced against brass, connected with gold leaf, very sensibly affects it; and, as far as we are able to judge, from the great collection of facts, all the substances in nature are capable of exhibiting the power. Its effects are, probably, as comprehensive as those of gravitation; and when they are thoroughly understood, they will probably be found not less important.

The voltaic battery was as an alarm-bell to experimenters in every part of Europe; and it served no less for demonstrating new properties in electricity, and for establishing the laws of this science, than as an instrument of discovery in other branches of knowledge; exhibiting relations between subjects before apparently without connection, and serving as a bond of unity between chemical and physical philosophy.

In so rich a harvest of discovery many were anxious to be partakers; and perhaps no equal period of philosophical history exhibits a more brilliant picture of the activity and power of the human mind, seeking for a new empire over the natural powers of things, than may be contemplated in the annals of the last eight years.

In Germany various new conditions of electrical action have been investigated by Ehrman and Ritter: to Ehrman we owe a history of the relations of different conductors to the Voltaic apparatus. And though Ritter, in some of his conclusions, seems to have followed the impulses of a strong imagination rather than the results of observation, yet the science is indebted to him for the invention of several happy combinations. His errors, as a theorist, seem to be derived from his indulgence in the peculiar literary taste of his country, where the metaphysical dogmas of Kant, which as far as I can learn are pseudo-platonism, are preferred before the doctrines of Bacon, Locke, and of Hartley—excellence and knowledge being rather sought for in the infant than in the adult state of his mind.

In Holland Van Marum has compared the powers of the greatest electrical machine in existence, that constructed by Mr. Cuthbertson at Haarlem, with the powers of the Voltaic apparatus; and has elucidated the action of the one by the operation of the other.

In Denmark Pfaff, and in Sweden Hissinger and Berzelius, have ascertained some curious relations of what have been called the chemical galvanic phenomena. And in France some valuable observations have been made by Vauquelin, Thenard, Biot, and Gay Lussac, on the construction of the Voltaic apparatus and its diversified powers.

Lastly, I must speak of what has been done in the British islands; but I scarcely know how to describe with propriety the distinguished labours of our countrymen. On such an occasion, it is not easy to avoid feelings of partiality; yet it seems to me, in strict philosophical justice, that what has been effected by them may be well put in competition with what has resulted from

the combined exertions of the philosophers of the continent of Europe.

It was in Britain, immediately after the first exhibition of the Voltaic instrument in 1800, that some of its most remarkable chemical powers were ascertained. It was in the same place that the first distinct demonstration of the identity of its effects with those of the electricity of the common machine was developed, and that it received the greatest improvements in its construction.

I should have infinite satisfaction in dwelling particularly on the advances made by every individual amongst British investigators, but, as I am connected with many of them by ties of friendship and of personal intercourse, I feel that it would be indelicate for me to assume the right of arbitrator, even where praise only can be bestowed. Their merits are universally acknowledged: concerning the development of new philosophical facts, there can be but one judgment, for facts are independent of fashion, taste, or caprice, subject to no code of criticism, the creations of truth, and durable as that nature to which they belong.

LECTURE I.—INTRODUCTORY TO ELECTRO-CHEMICAL SCIENCE.*

It affords me the most sincere pleasure to be able to appear again before you. There is no desire more alive and ardent in my mind than that of having it in my power to combine experiments, made for the advancement of science, with the details of public lectures.

The present course admits of such an union, and I shall consider my exertions and labour in delivering it, as more than compensated for by the satisfaction I shall receive if the end to which my wishes are so strongly directed be in any manner accomplished.

I speak of labour and exertion not with the view of making a parade of difficulties, and of the merit of overcoming them, but merely to prepare for and to ask you to consider with indulgence what I am convinced will be a very imperfect work.

The subject you will feel is in a great measure unexplored. Little or no assistance in the investigation can be derived from books, and I am obliged to trust almost wholly to my own efforts, and to my own limited information. Had I been able to make my preparations in full health and in full time, I should have possessed more confidence; and, the novelty and importance of the subject would have been sources rather of hope

* [Delivered in 1808, on the 12th of March, after recovery from severe illness, which followed the decomposition of the fixed alkalies. Vide Vol. I. p. 113.]

than of fear; but the long confinement and severe illness which I have sustained, have prevented me from maturely arranging my plans. Many ideas in full vividness before, I am unable at this moment to recover; and investigations have been left incomplete, which I had hoped to be able now to bring before you, and to connect with some brilliant results. You must regard this attempt as an unfinished building, of which the scaffolding has failed, and demands repair; unfinished, but not neglected, to be an object of future care and labour,—unfinished not from a want of will in the architect to pursue his object, but from a want of power.

Electro-chemical science relates to all the phenomena in which electrical and chemical agencies are concerned. It may be asked, why has this new term been adopted? I trust not without good reasons. Electricity or electrical science has always been applied to a particular series of brilliant yet insulated effects in which chemical changes had no share. The word galvanism has likewise always been understood in a limited sense, and it could not with propriety be made to include a general view of corpuscular philosophy; and perhaps the name of Galvani has been already too often associated with the later philosophical truths. This observer was indeed the fortunate and accidental discoverer of a most important fact, but he mistook the interpretation, and pursued it to no extent; and it is to the penetrating genius of Volta that we owe the most happy elucidations, and powerful instruments of the science; but even the name of Voltaism could not be used with strict philosophical justice, for his discoveries comprehended electrical phenomena alone, and the most important results which have been since ascer-

tained are chemical, and connected with the general system of operations in art and in nature.

In so extensive a field of investigation, a general view of the objects of discussion, of their order, connections, and applications, cannot be improper. It will be tedious, but it is necessary; and to all who may follow the course not merely from curiosity, or the hope of being amused, but from the genuine love of knowledge, I am convinced it will be useful. Amidst the numerous subjects of experiment, you will find many that have been before introduced to you, yet the most interesting will be of a novel character. You will find that something has been accomplished, which I had ventured to hope for, even within the short period that has elapsed since I last had the honour of addressing you. And it may be a source of gratification to know that this branch of knowledge which you attended to, and fostered even in its infant state, whilst helpless in its cradle, has rapidly increased in strength and power, and has advanced if not to the full form and vigour of manhood, at least, to the freshness and promise of youth.

Amidst the multifarious phenomena of the external world, an immense number of similitudes or analogies, appear to the investigating mind. To arrange them, and to discover new ones by more minute observations, or experimental means, is a principal business of philosophy; and the legitimate practice, that sanctioned by the precepts of Bacon, and the example of Newton, is to proceed from particular instances to general ones, and to found hypotheses upon facts to be rejected or adopted according as they are contradictory or conformable to new discoveries.

I trust I shall be guided throughout the whole pro-

gress of inquiry by these principles of research; and in employing them, the first subject for discussion will be that which most applies, and which is most nearly related to the whole series of phenomena,—the subject of electrical attraction and repulsion.

Certain bodies, when heated or rubbed, draw to them very light substances; such are sealing-wax, or glass, which when thus excited, attract feathers, bits of paper or gold leaf. This is remarkable; but it is more remarkable that a light substance placed in a condition to be attracted by heated glass, is driven away or repelled by heated sealing-wax.

It is on facts of this kind which may be almost infinitely multiplied, that the idea of positive and negative electricity has been established. It will not be necessary for us to discuss the remote cause of the phenomenon. Whether the attractions depend upon one very subtile fluid existing in the pores of all common bodies in larger or smaller quantities; or upon two etherial fluids, capable as it were of neutralizing each other by combination, will be objects of inquiry for a more enlightened and distant period of the science, which as yet is too immature to admit of generalizations, even less refined. The difference in the electrical states of different bodies, occasioned by heat or friction, has long been known. But that bodies existed naturally negative and positive with regard to each other, independent of any mechanical or chemical changes is a fact of late discovery. A piece of zinc and a piece of copper when made to touch each other and separated, are found by delicate tests, the one negative, the other positive. A plate of glass made to touch a surface of quicksilver is found positive, and the quicksilver negative.

An immense number of similar instances exist.

Whenever adequate means of investigation have been employed, the phenomenon has been observed; and it seems to apply to all bodies differing in nature and constitution.

The development of the law, and the illustration of it by experiments, must occupy much of our attention, from the importance of it in principle, and from the extent of its applications; and it will be found to offer explanations of a number of effects hitherto insulated or obscure.

In the operation of common electrical machines, the electrical fluid has been generally conceived as pressed out of the glass by the influence of friction. The theory on the principle of natural electrical energy, will certainly be less complicated and mechanical. Friction will be considered merely as a succession of contacts, more effectually exhibiting what may be shown, even by a single contact, the natural positive state of glass, with regard to the metallic amalgam or silk of the cushion.

A plate of zinc and a plate of silver, brought in contact with each other, and applied to the tongue, produce a strong caustic sensation. This the experiment of Sulzer, and the analogous experiment of Galvani, on the excitation of the muscles of animals, which for so long a time were supposed to be demonstrative of new recondite principles, intimately connected with vitality in organic bodies, may be solved in the most perfect manner, according to the new elucidations, as simple facts of common electrical action.

In the grand arrangements of nature, with every alteration of place, with every new contact of bodies, electrical effects must necessarily be connected, which require to be considered, in examining the general laws

of the changes and transmutations of matter. The materials of the air, of the solid surface, and of the ocean, differ in electrical energy. With all their mechanical movements in respect to each other, there must be a disturbance of the electrical equilibrium; and, on this idea, may be explained many of the exhibitions of electrical effects, constantly taking place in nature, which, under common circumstances, proceeding slowly and gradually, are connected with the daily and uniform order of events; but which, in other cases, appear to be the immediate or remote causes of remarkable and awful phenomena, and associated with the whirlwind, the hurricane, and the earthquake.

Excitation, by contact, seems to be a great cause of the common phenomena of electrical attraction and repulsion; but there is another cause, in what is called the alteration of the electrical capacity of bodies, in consequence of alterations in their specific forms or composition. Bodies expanding, enlarging in their dimensions, from the influence of heat, become negative. Bodies contracting, suffering a diminution of volume by cooling, on the contrary, are positive—and, as it were, communicate electricity to the surrounding bodies, whatever may be their natural energies. Thus, water thrown upon a red-hot plate of silver, is expanded to many hundred times its former volume; and it renders the silver negative. But steam thrown upon a cold plate of silver, so as to be condensed into water, makes it positive.

In considering the common and artificial phenomena of electricity, we shall often have occasion to recur to the principle of the change of electrical capacity. For, in processes of friction, the heat produced often alters the capacities of the acting substances unequally; and

hence modifies the results which would arise from the pure exhibition of their electrical energies.

In natural phenomena, this law of capacity acts a still more important part. By evaporation, from the diffusion of water in air, the surface is rendered negative, —and by the condensation of moisture in the upper regions of the atmosphere, its strata become positive; and water being a conducting substance, clouds are changed: and in returning their contents to the sources whence they spring, they moisten the earth in rain, dew, or mist, and occasion lightning and thunder.

These facts of electrical excitement, are primary; but there are others, which though secondary, will require an attentive investigation; those connected with what is called propagated and induced electricity.

Different bodies possess very different powers with regard to electrical transfer or communication. Some are said to be perfect conductors; such as metals—that is to say, the electrical influence rapidly pervades their parts. Others are imperfect conductors,—which, as it were, expose obstacles to its passage, such as water; which, according to Mr. Cavendish's computation, conducts 400,000,000 times less perfectly than iron. Others, again, are non-conductors, such as glass, being impermeable to electricity. Even amongst conductors, there are great differences in their relations to the different states of electrical excitement; thus, some conduct negative electricity only, as soap:—and others, positive electricity only, as the flame of a candle;—and these remarkable powers, established by the late researches of Ehrman, will be found to lead to important conclusions; and in some measure to connect the mechanical and chemical properties of matter.

A body positively electrified, renders another body

in its vicinity, negative; and *vice versa*. A body negatively electrified, renders some contiguous body positive; and, if the electricities are exalted, a discharge results.

This is the fact of induction,—of which a number of elucidations will be offered to you. It is on this principle, that the transfer of electricity in the common electrical machine, from the glass to the conductor, is performed. And on this depends the operation of the Leyden jar, and the battery by which an immense accumulation of electricity is produced, and some of its great effects in nature imitated. Conductors for preserving buildings from the effects of lightning act upon the principle of being induced into an opposite state from that of the cloud or the atmosphere; and presenting points only, they occasion a slow discharge of electricity, and disperse this active and often terrible agent in harmless and beautiful flashes.

Clouds, when charged with negative electricity, induce positive electricity upon other clouds in their neighbourhood; and these again occasion the opposite state in some other contiguous matter; and hence by an alternation of circumstances and a communication with the surface of the earth, the equilibrium is gradually restored.

It is on the law of induction, combined with the general property of electrical energy, that the powers of the most wonderful and important electrical instrument ever discovered depend. You must perceive that I mean what has been called the galvanic battery, or the apparatus of Volta.

I have mentioned that a piece of zinc and copper, when brought in contact, are in the relations of negative and positive; and when many series of this kind are

constructed, with water or an imperfect fluid conductor interposed, the electrical power increases in an uniform ratio with the number, negative electricity being induced upon every plate naturally negative, and positive electricity upon every plate naturally positive.

The construction of the voltaic instrument, its agencies, and the theory of its operation, will be demonstrated upon an extensive scale. The battery before you is a small part of a series consisting of 600 plates of the same size, a combination at least four times as powerful as any that has hitherto been constructed.

Whatever is brilliant or impressive in the experiments made in this course of lectures, will be owing to the agencies of this instrument; but it has been provided not so much for the purpose of exhibiting what is already known, which might be accomplished by more simple means, as for the end of new research and with the hope of new discovery.

I trust you will not consider me as actuated by any sentiment of vanity, when I say that the voltaic combination will be presented to you in these lectures under a novel point of view, as offering the most efficient means of providing new changes, as being the most powerful agent that has yet been discovered for effecting decompositions and new combinations, and thus superseding most of the common chemical powers.

In this it will be seen that Volta has presented to us a key which promises to lay open some of the most mysterious recesses of nature: till this discovery, our means were limited, the field of pneumatic research had been exhausted, and little remained for the experimentalist except laborious and minute processes. There is now before us a boundless prospect of novelty in

science; a country unexplored, but noble and fertile in aspect; a land of promise in philosophy.

After having considered the physical powers and laws of electricity, and the combinations invented for exhibiting its properties, the next object will be the discussion of its relations to the general chemical operations of matter; and this inquiry will naturally follow the history of the voltaic battery, and will be copious in facts, instances, and inductions.

That bodies differing in nature blend or unite with each other into a common mass possessed of new properties, is the most simple and ancient fact of chemical affinity; but that all bodies which have been accurately examined so combining or blending, are possessed of opposite electrical energies, was for the first time made publicly known in the course of the last year.

Bodies possessed of similar electrical energies, according to the common laws of electrical attraction and repulsion, ought to repel each other. Bodies possessed of different electrical energies, ought to attract each other. The question may be asked then;—Is not what has been always called chemical affinity merely the union or coalescence of particles naturally in opposite electrical states? And are not the chemical attractions of particles and the electrical attractions of masses owing to one property and governed by one simple law?

There are extensive series of phenomena which favour this idea; and as yet no contradictory fact has occurred, and the electrical and chemical functions of bodies as far as our knowledge extends, exist only together, and are modified, created, and destroyed at the same time.

Thus a metal is naturally positive with regard to

oxygen; when this its electricity is increased, it combines with oxygen with more facility; but if it is made negative, it refuses to combine or remain in union, and repulsion instead of attraction takes place.

Acids in general again are negative; alkalies, earths, and metallic oxides positive; and as it is well known they unite to form new compounds: but if an acid be made positive by artificial means, it refuses to combine with alkalies; or if alkalies be made negative, they will no longer act upon acids; and by employing different electricities, in consequence of those effects, neutral salts and an immense number of other compounds may be decomposed and their elements obtained.

Whatever be the fate of the opinion that electrical energy and chemical attraction are one and the same power, the facts of the dependence of the chemical arrangements of matter upon electrical functions will be permanent, and will be found to offer adequate and simple methods for determining the nature and species of bodies, and the most refined and exalted powers of analysis.

Bodies found on chemical examination to consist either wholly or principally of inflammable matter, are naturally highly positive. Bodies on the contrary consisting either entirely or chiefly of matter capable of supporting combustion, are naturally negative; and where the two electrical powers are artificially exhibited in the same system of bodies, oxygen and such substances as contain oxygen in excess, are uniformly brought into a state of rest in the sphere of positive electricity; and hydrogen, sulphur, phosphorus, metals, in short combustible bodies in general, are repelled from the sphere of positive electricity, and attracted into that of negative electricity. Metallic oxides, earths, and alkalies, are all

positive, and are attracted by negatively electrified surfaces; but metallic oxides consist of a large portion of different inflammable matters combined with a small portion of oxygen. Analogy induced me to believe that the alkalies and earths were similar compounds; and experiments, as far as they have gone, have converted this conjecture into a truth.

In these developments of new elements, new instruments of research are continually produced, their scientific applications are almost boundless, and the power of electrical decomposition will probably exhibit to us all the elements of matter possessing the functions of positive and negative, of burning and of supporting combustion.

The energy of combination belongs, in the highest degree, to simple bodies, and it almost disappears in very complex substances; and this law is immediately subservient to the perfection of the arrangements of matter, in living organs.

The elements of the atmosphere, the ocean, and the solid parts of the earth, are constantly acting upon each other, so as to produce combinations fitted for the ends of life. Vegetables, by assimilating water, oxygen, and inflammable principles existing in the soil, form materials for a more perfect structure adapted to resist the common destructive powers of nature. By mechanical agencies, matter is divided so as to be susceptible of the operation of chemical laws; and by chemical laws, it is combined for the purposes of animation, its ultimate and highest destination.

It has been conjectured that some even of the functions of living beings, depend upon electrical changes; and the facts of the galvanic excitation of muscles, after the death of animals, has led to the idea.

This subject will be considered; and though it cannot be much enlightened by our existing knowledge, yet this knowledge will be sufficient to overturn some of the bold hypotheses which have been attached to it.

Physiology is as yet the most independent and least advanced of the sciences. It unfolds the most admirable effects; but we are unable to trace causes. In referring muscular contraction to electrical changes, we do not advance a step;--it is mere supposition.

Electricity most probably acts as a stimulus alone, in common experiments. And the only electrical arrangements known in animal structures,—those of the torpedo, gymnotus, and other fishes—are not organs of vitality, but instruments of attack or defence.

When the grand discoveries of Newton were first developed, it was the fashion amongst speculators to refer muscular motion, and the motive powers of animals, to mechanical causes; and wedges, and springs, and elastic globules were the machinery imagined.

With the pneumatic chemistry, arose the pneumatic physiology; when oxygen, hydrogen, azote, and carbon became the supposed energetic agents in living nature.

The experiments of Galvani introduced positive and negative electricity, and the idea of muscles and nerves operating on the principle of the Leyden phial.

Most of these dreams have long ago passed away. All of them will pass away. Life appears to us through sensible phenomena; but the powers concerned in its operations, must for ever be hidden. To apply the laws of common matter to organized structures, is seeking the living amongst the dead—looking for the ruler amidst slaves. That which sees, will not be visible;—that which touches, will not be felt;—that which commands sensations, will not be their subject.

LECTURE II.—ELECTRO-CHEMICAL SCIENCE.*

Matter appears to us, through the medium of the sensations of touch and of vision, and all our judgments with regard to external things, are founded upon the correspondence or coincidence of these two senses. As the impressions we derive from them are almost infinitely diversified, we assume an equal diversity of external objects. As the images of things appear to us in parts, and in successions, we assume divisibility, and extension as properties of matter, and this mode of reasoning, which is derived immediately from the powers of the human understanding, is justly applied, in its various details, to the phenomena of the external universe.

Change is the essence of all the operations in nature, and change may constantly be referred to motion. But for motion there must be a moving cause, and this necessarily implies the existence of active powers.

In the great phenomena of the solar system, the various and harmonious mutations of the heavenly bodies are accounted for, by the supposition of two energies operating upon matter, gravitation, and the projectile force, and the laws of these have been submitted to calculation by the power and sagacity of human genius.

In the terrestrial order of events, the uniformity of operating causes is less evident; but still it may be traced, and that even in strict analogies. By the tendencies of substances, to approach or recede from each

* [It belonged to the same course as the preceding.]

other, the various alterations of the forms of things, whether obvious or obscure, rapid or slow, may be explained, and attraction and repulsion established as motive agents or influences.

In our discussions on every part of the science of nature, we are obliged to recur to these powers. But though sound philosophy permits us to allow them as active, it is far from considering them as inherent in or necessarily attached to matter. After the example of Newton, they may be considered as principal, but not ultimate, as secondary, and not primary causes.

In nature nothing can be truly said to be automatic,—one order of events flows from another, an immense number of phenomena depend upon a single law, but all may be considered as a work of mechanism, and of divine institution. In human inventions, springs may move springs, and wheels wheels, but the first motion, and the regulation, must be derived from the artist. Sounds may be occasioned by undulations in the air; undulations in the air may proceed from vibrations of strings; but the impulse and the melody must arise from the master.

Every species of attraction and repulsion that we are acquainted with may be the result of one grand and universally operating law; and the further we advance in science the more this idea becomes probable. At present, however, it is necessary to make distinctions between gravitation, cohesion, magnetic, and electrical attraction, and to follow the facts, awaiting patiently the progress of discovery, and the perfection of analogies.

The phenomena of electrical attraction and repulsion, the immediate objects of our inquiry, are not merely important in themselves, but they are guides in our future progress in electro-chemical science, and they will therefore require a full experimental demonstration.

When a rod of glass is heated, and brought into the vicinity of a pith-ball, the pith-ball moves towards it, and, for a moment, adheres to it. But if it be made to act upon two pith-balls, these will repel each other, and, in this case, as it is evident they have both received a similar impression, they are said to be in similar electrical states, or similarly electrified.

(INSTANCE.)

When a pith-ball, or other light substance, is acted on by glass, and another pith-ball by a piece of sulphur, these balls will attract each other; and, as they are acted upon by two different bodies, and present phenomena different from those they would present if acted on by the same body, they are said to be in different electrical states, or differently electrified.

(INSTANCE.)

Two pith-balls, that repel each other in consequence of the agency of glass, will have their repulsive energy not destroyed, but increased, by the approach of heated or rubbed rock-crystal, but they will lose it if they are acted on by heated sulphur.

(INSTANCE.)

Two balls, likewise made to repel each other by the agency of sulphur, will repel each other still more by the approach of resin or sealing-wax; but their repulsion will cease by the influence of heated glass.

(INSTANCE.)

The electricity produced by sealing-wax, then seems, as it were, to destroy, or, as it were, neutralize the electricity produced by glass, and hence has been founded

the distinction of two electricities,—*vitreous,* the electricity of glass,—*resinous,* the electricity of sealing-wax.

In the nomenclature of electricity, commonly adopted in this country, positive, or plus, is synonymous with vitreous,—negative or minus, with resinous electricity. The words positive and negative, plus and minus, are sanctioned by the authority of Franklin, who has accounted for the phenomena by the supposition of one fluid only in excess in bodies possessing the vitreous electricity,—in deficiency in those possessing the resinous electricity.

It is unfortunate for the diffusion of science, that any terms should be in common use which imply hypothetical ideas; but, in the present early stage of the investigation, it is better to adopt even an imperfect language than to form a new one. The denominations, as I shall use them, you will have the goodness to consider as merely signifying the unknown causes of a certain series of facts.

By the common electrical machine of the construction of Nairne, we may gain some good elucidations of the effects referred to positive and negative electricity.

The two cylinders of metal, opposite to the glass, are in an active state. Were they similarly electrified, the effect ought to be increased by connecting them, but it is not increased, it is destroyed,—they must therefore be in opposite states.

Two cylinders made of paper, covered with leaf gold, placed in contact with either of the metallic cylinders, and possessed of freedom of motion, repel each other when electrified; but if the paper cylinders be distributed one upon each of the metallic cylinders, they will then attract each other, distinctly demonstrating the two properties, the negative and the positive.

(INSTANCE.)

Electrical attractions and repulsions form the only measures that we have of the force or strength of electricity, and furnish the only tests in our possession of the difference between the two kinds of action.

The common gold-leaf electrometer is founded upon the principle of repulsion, indicating identity of electrization, and of attraction indicating diversity, or contrariety; it is composed of two pieces of leaf-gold, attached near each other, and capable of being acted on by an electrified body at the same time. In proportion as the repulsion between the two pieces of gold leaf is great, so in proportion is the electricity judged to be strong. And when the repulsion, produced by the contact of any body, is still further increased by the contact or approach of electrified glass, that body is considered as positive; but if the leaves collapse, it is then considered as negative.

(INSTANCE.)

And in this way it is easy to examine and to determine the electrical states of bodies.

This happy and delicate invention we owe to Mr. Bennett, who contrived by means of it to exhibit electricities which before his time had never been supposed to exist. There is another electrometer on the same principle of repulsion, which was first constructed by Colomb, and presented by him to the Academy of Sciences of Paris. It consists of a pith-ball covered with gold leaf attached to one end of a fine metallic wire, and balanced at the other by a piece of metallic leaf. It is suspended by a very delicate wire of gold or silver, or the single filament of a silk worm; and on the ease with which the wire or filament is turned or twisted the sensibility of the instrument depends.

(INSTANCE.)

It is evident from the various phenomena you have already witnessed that the agent or agents occasioning electrical effects are capable of being transferred or communicated from one body or system of bodies to others, and it is necessary to inquire what are the circumstances of this phenomenon, and whether different substances are possessed of distinct powers, or of the same powers with regard to communication or transfer.

We find in our first and most simple experiments remarkable differences, and we are able to arrange bodies under three distinct classes, in consequence of their relation to this property, into conductors, imperfect conductors, and non-conductors.

Bodies are called conductors when they readily admit the passage of electricity along their parts.

(INSTANCE.)

All the metals are perfect conductors; charcoal likewise belongs to this class, and some of the metallic ores.

An imperfect conductor is a substance which, though it admits the passage of electricity, yet seems to oppose obstacles to it, or at least conveys it very slowly.

(INSTANCE.)

Water and fluids containing water are imperfect conductors; so likewise are the greater number of animal and vegetable substances in their common state.

Bodies that are wholly incapable of suffering the electrical fluid to move along their surfaces are called non-conductors. Such is glass.

(INSTANCE.)

Hence non-conductors are said to insulate, to prevent

the transfer or communication of electricity, and hence they form a necessary part of all our apparatus for the artificial excitement of electricity. Stones and gems of all kinds, amber, sulphur, resin, air, and most of the fluid and solid highly inflammable bodies are non-conductors.

It must however be understood that in each of these three classes there may be differences with regard to the degree of conducting energy.

In respect to the perfect conductors, such as the metals and charcoal, it is not easy to find means of determining this point. The finest metallic wire or the thinnest filament of well-burnt charcoal seems capable of conveying instantaneously, or rather in no perceptible time, the largest quantity of electricity. And the only limit in experiments of this kind is the fusibility of metals. A wire of tin or of lead will convey a large quantity of electricity as well and in the same manner as a wire of iron or platina, as long as the discharge is not capable of producing sufficient heat to melt them, and it is only from the loss of continuity that their power is destroyed, for the fused metals are still perfect conductors.

(INSTANCE.

Galvanic battery.—Wire of tin.—Wire of platinum.)

A still higher discharge would fuse even *platina;* and where buildings furnished with conductors are injured by lightning, it generally happens that the conductor is melted, the discharge being too intense to pass through it without destroying the aggregation of the metal.

The difference of the degree of the conducting function in different imperfect conductors is known by the

time they require to discharge equal quantities of electricity, *i. e.* the conducting power is inversely as the time. If this fine tube be filled with alcohol or highly rectified spirits, it will require more than a minute to discharge the jar by means of it, whereas water would discharge it in less than a second; so that the conducting power of water must be at least sixty times as great as that of alcohol, which is a very imperfect conductor.

(INSTANCE.)

Again, if a glass-tube of a finer bore were filled with water, and made to discharge a jar of such a size, and in such a state, that it required three minutes for the process; the same tube filled with oil of vitroil, or sulphuric acid, would discharge it in an imperceptible time, in much less than a second; so that it must conduct many hundred times better than water.

In general, salts, acids, or alkalies dissolved in water, considerably increase its conducting power; whilst inflammable fluids, such as spirits and ether, diminish this power.

Mr. Cavendish has computed that sea-water conducts 100 times better than common water; and a saturated solution of salt, 7 times as well as sea-water.

Sulphuric acid seems the best of the imperfect conductors; still there is an immense distance between its power and those of the metals. A surface of sulphuric acid of considerable size, is required to carry off the whole discharge of this battery; but the least visible surface of metal, is adequate to the effect,—so that the conducting power must be at least some hundred of thousand times greater.

Some of the worst of the imperfect conductors, may be said to form the link between this class, and the class

of non-conductors; such are very pure alcohol and ether.

(INSTANCE.)

Amongst the non-conductors, the most perfect are the gems, glass, and hard bodies of a vitreous texture, amber, resin, wax. Crystalline salts follow next in order of insulating power;—after these the fixed oils; and last of all, the volatile oils.

As we are unacquainted with the intimate nature of the agent producing electricity, so we are likewise ignorant of that peculiar constitution of bodies, on which their different relations to the conducting energy depend.

It might at first view be supposed that the densest bodies conducted best. For air, and oils, and resins are of extremely low specific gravity; and the metals are of high specific gravity; but this idea is wholly untenable. For barytes, which is four times as heavy as water, is a perfect non-conductor; and the new substance which forms the basis of the vegetable alkali, though lighter than ether or naptha, conducts, as well as platina, the heaviest body in nature.

Any change, however slight in the chemical constitution or form of body, is almost always connected with a corresponding change in its conducting energy. The metals, by absorbing a small quantity of pure air, become non-conductors. Charcoal, as long as it flames by heat—that is, as long as it contains any inflammable air or hydrogen, is a non-conductor; but when it bears a white heat without flaming, that is, when it is free from hydrogen, it conducts as well as the metals. Water, when converted into ice or steam, is a non-conductor; and glass, or any of the saline substances, when rendered fluid by heat, become conductors.

Solids and fluids suffer no change in their conducting powers, by any mere mechanical alteration or division of their parts, so long as they retain their own peculiar forms; their powers seem independent of expansion from heat, or of contraction by cold. This, however, may be owing to the circumstance that the changes in volume we are capable of producing are too small to occasion any appreciable differences; for with airs, which we are capable of expanding or contracting to a great extent, without destroying their peculiar form, the case is very different. Air, in its common state so good an isolating substance, becomes, when considerably rarefied, (either by heat, or by removing pressure from it,) very permeable to the electrical agency; and from its transparent nature, offers a very beautiful appearance during the passage of electricity through its parts.

(INSTANCE.)

These exhibitions have been considered as imitations upon a small scale of the magnificent natural appearance of the Aurora Borealis and Australis. That the northern lights must depend upon the discharge of electricity through highly rarefied air, there is the strongest reason to believe; (but the theory of the excitation of this electricity, admits of some discussion; and the question will properly belong to another part of the course.)

Perfect conductors, as we have seen, carry off electricity, under all circumstances, with a rapidity that cannot be measured. This even happens, whatever be the extent of the discharging chain; or of the charged surface to which the electricity belongs. In an experiment made about fifty years ago by the French acade-

mecians, a discharge was passed along wires that extended for nearly two miles; but it took place in no sensible time; and the spark at one extremity and the other was simultaneously visible. A similar result was obtained in England, the extension of the chain being nearly to four miles.

Imperfect conductors seem to obey the same law as to the rapidity of the motion of the electricity, which they are capable of carrying off from charged bodies. Thus, the electrical shock has been transmitted along the Thames; and the signals being made at the time of the discharge at one point, and of the shock being experienced at the opposite point, these signals always appeared at the same instant; so that there was no period between them capable of being measured.

In natural appearances, likewise, now that we have full proof of the identity of lightning and electricity, we have stronger evidence of the circumstance. Sound moves at the rate of eight miles in a minute, and a considerable interval often occurs between the appearance of the lightning and the first sound of thunder, and the noise consequent on a single flash, often continues for more than a minute; which proves that the path of the electricity along the moist air, must have been many miles in extent, though to us it appears only as a single and instantaneous line of light.

We have already witnessed, however, that where imperfect conductors are used for discharging large quantities of electricity, they do not carry it off at once, but require a certain time for the operation; and (it is a circumstance to which I beg particularly to call your attention,) that they will carry off or transmit the same quantity of electricity in a longer time when it is diffused

over a large surface, than when it is concentrated on a small one.

Let the electricity of this phial, which could be discharged by this column of water by a single contact, be communicated to a jar of six times the surface, and it will require a much longer time for its discharge,—and by using a jar of a thousand times the surface, it would have no perceptible effect. In these cases, the power of motion of the electricity, or as it is usually called, its intensity, is diminished in proportion to the increase of surface; and the efficacy of imperfect conductors, in carrying off electricity, is directly as its intensity.

There is a measure of the intensity or power of motion of electricity in the distance, through which a spark will pass in air to a conductor; and the intensity is said to be less in proportion as this distance is smaller. This jar, highly charged, will give a spark which would pass through half an inch of air; but the same quantity of electricity transferred into this jar, would not pass through a single line; and if the transfer had been made into a battery of ten or twelve such jars, the effect of the spark could only be produced by absolute contact of the metallic surfaces.

It was from a want of attention to the principle, that imperfect conductors act only very feebly upon large quantities of electricity diffused over large surfaces, or in a low state of intensity, that there existed so much discussion with regard to the identity or non-identity of Galvanism and electricity. A view of the phenomena, according to the ideas that have been just stated, immediately removes every doubt.

In the Voltaic battery the intensity of the electricity is so low, that it does not pass through any sensible

distance of air; and of course such electricity could not be expected to be very rapidly carried off by imperfectly conducting bodies, though it is instantaneously transported by metals.

This battery contains a large quantity of surface, and the electricity is of so low an intensity, that the wires must be brought in contact to produce a spark. We cannot, therefore, expect that it should be rapidly carried off by water, or the human body; but we might expect that it would produce greater effects upon better imperfect conductors, and its full effects upon perfect conductors.

(INSTANCES.)

It is by consequence of this principle that the torpedo and the gymnotus preserve and exert the energy of their electrical organs in water. The electricity exists in them in large quantities, but of so low an intensity that the spark barely passes through a sensible space in the air. Hence water insulates this electricity almost as much as air insulates common electricity. It is upon living bodies, which, whilst the skin is moist, are of the highest order of imperfect conductors, that its power is exerted; and there can be little doubt, but that if the electricity of the eel of Surinam were passed through thin metallic wires, it would occasion their ignition in the same manner as that of the Voltaic instrument.

We have considered, with some minuteness, the circumstances which influence the communication or transfer of electricity, but how does this electricity exist? what are the causes of its appearance? These are questions which may with propriety be started, and they are

questions which I shall endeavour, in some measure, to answer.

The first and most important principle, with regard to the appearance or excitation of electricity, is the principle of electrization by contact, or the principle of electrical energy.

These plates of zinc and copper are insulated by means of glass handles. If I apply them, one after the other, to electrometers they will produce no effect; but if I make them touch each other, and then apply them, each will communicate a slight electrical charge, which, by many successive contacts, may be increased so far as to be ascertained, and the electricity of the zinc is always found positive, and that of the copper negative.

(INSTANCE.)

It is not possible, in a room like this, in which the air is rendered conducting by many causes, to exhibit the charge of the electrometer; the best mode of making the experiment is by a small condenser of this kind; seven or eight contacts are generally sufficient, and it will be seen that the leaves which separate from the effect of the zinc will repel each other still further on the approach of excited glass; but when the copper has communicated the charge, they will close on the approach of glass. An evident method of perceiving the excitation by contact is, by causing the two metals to act upon the animal organs, and in this case the electrical sensation is very obvious.

(INSTANCE.)

The effect of the electrization by contact belongs, in a high degree, to zinc and copper, but it may likewise be exhibited, in a greater or less degree, by combina-

tions of all other metals; and it is not at all limited to the metallic kingdom, for it seems to belong to bodies in general, to fluid and aëriform substances as well as to solids, to imperfect and non-conductors as well as to perfect conductors.

A plate of glass, laid upon a surface of dry quicksilver, is found positive after contact—the quicksilver is negative. The case is similar, if the plate be laid upon an amalgam of quicksilver, or upon a piece of silk; and the experiment of the excitation of electricity by the contact of glass with other substances is made upon a great scale in the electrical machine, in the continued impression produced by friction.

Liver of sulphur, or an alkaline solution poured into a metallic cup, renders it negative; but an acid solution makes it positive. This effect may be made evident to the electrometer by several combinations, but a single one is sufficient to exhibit the agency upon the legs of frogs.

When a metallic plate is made to touch crystals of the benzoic acid, it is found positive after contact.

But if it were made to touch dry quicklime, it would be found negative.

And a piece of dry quicklime placed upon the acid would be rendered positive, and the acid negative.

In the general arrangement of bodies as affected by contact, zinc is positive with regard to all other metals, manganese, iron, tin, lead, arsenic, antimony, copper, nickel, silver, gold, and platina, form a series in which every metal is negative with regard to those placed before it, and positive with regard to those placed after it.

The metals in general seem to be positive with respect to all bodies except alkaline, and perhaps earthy

substances, sulphur and phosphorus; and the acids, as far as they have been examined, are negative with regard to all other substances; and amongst the gasses those that contain oxygen seem to be negative with respect to all that contain inflammable matter.

As the electromotive power, or electrical energy of contact, so generally belongs to bodies differing in species, it must necessarily be in continued operation in all the different kingdoms of nature. The particles of the air cannot move upon the surface of the earth, or upon the waters, without producing some electrical change. The motions of the fluids of the globe must be connected with similar effects, and even in the solid strata, beneath the surface, the contact of metallic ores, by the rocks with which they are enveloped, and the association of the different earths, in a moist state, may be sources of alteration in those parts of the system which appear most fixed and immutable.

In common and obvious facts, which are constantly before our eyes, there are many exhibitions of the electrical effects of contact. In our culinary vessels composed of more than one metal, or containing solder, the greatest effect of corrosion is always at the points of contact of the different substances. Iron nails soon wear out when used to attach copper sheeting to ships, and iron pins employed to attach lead to the roofs of buildings rust with great rapidity, which is owing to the chemical operations being increased by the electrical energy of contact. Fermented liquors, which usually contain either the carbonic acid, or some other acid matter, are said to produce some little difference of effect on the palate when taken out of metallic vessels or vessels of glass, and this may naturally be referred to the electricity excited by the contact of the metal

and the fluid; and the civilized ancients, who, having no glass, chiefly drank their wines from goblets of metal, and often either silver or gold, must have had constant experience of this electrical taste. Many other instances might be given; and this principle of explanation has been sometimes carried even to a ludicrous extent; thus I have heard it asserted, that a pinch of snuff has a different flavour or odour when taken out of a metallic box, than when it is taken out of a box of wood or shell; which, if it be true, cannot depend on electricity, for no electrical circle is formed in the operation of snuff-taking.

After all that has been stated with regard to the electrical energy or electromotive power of contact, it may perhaps be still asked, is it an ultimate principle?—cannot it be referred to some more general law?

To this the simple reply is, it possibly may not be an ultimate principle, it possibly may, in some advanced age of science, be even referred to a more general law.

But we must reason in natural philosophy not from what we hope, or even expect, but from what we perceive.

The production of positive and negative electricity, by the contact of two bodies, cannot be referred to a chemical agency, for the electrical effects cease the moment chemical combinations begin. Thus zinc and quicksilver, or an alkali and an acid, as long as they are in contact without uniting, give strong marks of electricity, but at the moment they begin to enter into union this electricity disappears.

The energy of contact cannot be owing to a mechanical cause, for it is exhibited without impulse and independent of pressure, and remains permanent, without any relation to motion.

We can no more explain why bodies should differ in specific weight, than why they should differ in their relations to the states of electricity; yet we acknowledge and admire the laws of gravitation. In all our theoretical discussions we must rest somewhere, and that resting place is the most secure where the imagination is controlled by facts and guided by experiments.

The idea of something analogous to electrical energy in bodies was conceived at a very early period, and the same pre-eminent genius which anticipated so many of the results of modern research, appears to have had an indistinct glimpse of this discovery. Newton, in the third book of his Optics, has said, "May not the electrical attractions be exercised by bodies in an imperceptible manner and constantly?"

The first experiments of electrization by contact were made by Bennett in 1787, but it is to Volta that we owe the development of it as a general property belonging to conductors. He has at once the glory of having discovered the most wonderful philosophical instrument existing, and of having ascertained the great principle of its mode of operation. The fact of the electrical energies of non-conductors is a later work, but after what had been done by the Philosopher of Pavia, it followed as an easy consequence.

I shall resume the subject of excitement by electrical energy, and by other modes in the next lecture. By degrees it will be found that these general facts, the developments of which I am convinced must be very tedious to you, will unfold some brilliant applications, and they are absolutely necessary. The most irksome and difficult business in the progress of scientific discussion, as in building is to lay the foundation. The materials must be of different kinds, and from different

sources; they cannot always be adapted to each other, and they usually appear without elegance or beauty, but the permanency and utility of the structure depend upon the labour and care with which they are arranged.

PARALLELS BETWEEN ART AND SCIENCE.*

"Cæterarum rerum studia, doctrina et preceptis, et arte constare: poetam natura ipsa valere."—Cic.

The characters of the poet and painter have been often compared: and the analogy between their objects and their methods is so striking, as to have been generally felt and acknowledged. Visible images constitute the great charm of poetry, and they are the elements of painting: and the end of both arts is to represent the admirable in nature, and to awaken pleasurable, useful, or noble feelings. Painting, however, appeals to the eye by immediate characters; it possesses a stronger chain of association with passion; it is a more distinct and energetic language, and acts first by awakening sensation and then ideas. Poetry is less forcible; for it operates only by imagination and memory, and not by immediate impression; unless indeed in the performances of the drama, or in impassioned recitation. A representation by words is inferior in strength to representation by images; but it has the advantage in being more varied, and capable of a more extensive application. It speaks of sentiments and thoughts and affections, which can never be delineated by the pencil; and it has within its power, not only the world of sensation, but likewise the world of intellect.

* [From "The Director," No. 19, 1807. Vide preliminary notice to this volume.]

In music the powers of art are infinitely more limited than in poetry or painting. The pleasure results from mere combinations of sounds; and is as transient as the motions of the air, by which they are produced. To communicate feeling is the highest attribute of the art. Its means are wholly inadequate to convey ideas: and the attempts at imitation have generally produced only a ludicrous effect. It has this advantage, however, over poetry and painting, that its influence is more immediate and instantaneous, and perceived without study or reflection; that it acts as if by enchantment, and appealing merely to sensation, yet subdues both imagination and memory; makes the soul obedient to its impulses, and creates for the time a world of its own.

The mechanical arts and the fine arts can hardly be compared; the objects of the first being utility, of the last, pleasure. The mechanical arts delight us only indirectly, and by indistinct associations; the fine arts either directly, or by immediate associations. The steam-engine may be an object of wonder, as connected with the power by which it was produced, and the power which it exerts; but to understand its beneficial effects requires extensive knowledge, or a long detail of facts. Mechanism in general is too complicated to produce any general effect of pleasure. Inventions are admired by the multitude, more on account of their novelty or strangeness, than on account of their use or ingenuity. The watch which is the guide of our time, is employed and considered with indifference: but we pay half-a-crown to see a self-moving spider of steel.

In the truths of the natural sciences there is, perhaps, a nearer analogy to the productions of the refined arts. The contemplation of the laws of the universe is connected with an immediate tranquil exaltation of mind,

and pure mental enjoyment. The perception of truth is almost as simple a feeling as the perception of beauty; and the genius of Newton, of Shakspeare, of Michael Angelo, and of Handel, are not very remote in character from each other. Imagination, as well as reason, is necessary to perfection in the philosophical mind. A rapidity of combination, a power of perceiving analogies, and of comparing them by facts, is the creative source of discovery. Discrimination and delicacy of sensation, so important in physical research, are other words for taste; and the love of nature is the same passion, as the love of the magnificent, the sublime, and the beautiful.

The pleasure derived from great philosophical discoveries is less popular and more limited in its immediate effect, than that derived from the refined arts; but it is more durable and less connected with fashion or caprice. Canvass and wood, and even stone, will decay. The work of a great artist loses all its spirit in the copy. Words are mutable and fleeting; and the genius of poetry is often dissipated in translation. The compositions of music may remain, but the hand of execution may be wanting. Nature cannot decay: the language of her interpreters will be the same in all times. It will be an universal tongue, speaking to all countries, and all ages, the excellence of the work, and the wisdom of the Creator.

[The following extracts from the author's Lectures are given with the same intention as the preceding examples of Lectures,—partly, but not chiefly, in illustration of his modes of thought and expression;—chiefly for the sake of the thoughts themselves and the sentiments expressed relative to the value of science and its interests, the spirit of scientific research, its objects and limits, and the kind of support or patronage which it merits and requires.]

[As examples of original research and discovery most materially affecting the doctrines of chemistry, it may be right to introduce an extract from a lecture for 1810, on oxymuriatic acid (as chlorine was then called,) and parts of a lecture delivered in the following year, on the same subject. They will, it is hoped, be interesting to the chemical reader, looking back with a curious regard on this period of chemical science; and serve to show the manner in which men of science were drawn to the author's lectures—and how their interest in them at the time was excited.

In the lecture for 1810, he says.] This theory (that oxymuriatic acid is a compound) has been received almost universally; and of all substances belonging to our chemical arrangements, oxymuriatic acid is that which has been considered as the most easy of decomposition—the one from which oxygen may be subtracted with the greatest ease.

The researches which I have lately made upon the decomposition of bodies, have given, however, views of this subject entirely different. Nothing is more easy than to make oxymuriatic acid enter into a new combination; but it is impossible, by any known means, to decompose it: whilst muriatic acid gas is easily decompounded and compounded—compounded from oxymuriatic acid and hydrogen, and decompounded into the same elements.

[He adds, and his remark strongly marks the time,

"To many of my audience what I am stating, will appear paradoxical, and perhaps absurd; yet it is susceptible of strict demonstration."

This demonstration is most clearly developed in the lecture for the following year, just alluded to, great part of which it seems desirable to insert, both for the purpose announced, and as another specimen of his mode of lecturing.]

The views which I brought forward last year in this room respecting oxymuriatic gas, were received with so much attention and candour, that I feel peculiar pleasure in being able to confirm and illustrate them by new facts, and in being able to demonstrate their useful applications.

Those to whom the science of chemistry is new, will, I flatter myself, give their immediate assent to the demonstrations brought forward; from those who have adopted other ideas, I shall ask assent only in consequence of the most rigorous examination. Accustomed myself for years to the same train of thinking, I have experienced great difficulties in conquering the prejudices adopted from the French school of chemistry, and strengthened by its nomenclature. In the physical sciences, there are much greater obstacles in overcoming old errors, than in discovering new truths. In the first case, the mind is fettered; but in the last, perfectly free in its progress.

Scheele, in the same elaborate experiments on manganese, in which he discovered oxygen (his fire-air) likewise discovered the extraordinary elastic fluid which is to be the subject of the present lecture.

It is made by distilling together common salt, manganese, and sulphuric acid.

(INSTANCE.)

Its colour is green; it is more than twice as heavy as air; its smell suffocating. Pelletier destroyed by it.

Destroys vegetable colours.

(INSTANCE.)

It supports the combustion of a candle; and metals burn in it spontaneously.

(INSTANCE.)

Scheele, soon after he had discovered this elastic fluid, named it dephlogisticated marine acid. Reasoning upon the Stahlian view of the nature of combustion, he regarded it as an undecompounded body. Manganese gives off dephlogisticated air, &c.

M. Lavoisier.—Berthollet's proof.

These opinions of Berthollet have been received for nearly thirty years; and no part of modern chemistry has been considered as so firmly established, or so happily elucidated; but we shall find that it is entirely false—the baseless fabric of a vision.

Water, we know, consists of oxygen and hydrogen; or whenever these bodies combine, water is the result.

Now, if oxymuriatic gas is muriatic acid, combined with oxygen, when hydrogen and oxygen are detonated together, a compound of water and muriatic acid ought to result. But this is not the case.

(INSTANCE.)

Nothing but muriatic acid gas is formed. And, if we expose muriatic acid gas to a metal, according to Berthollet's notion, there ought to be no action; but we shall find the contrary the case.

(INSTANCE.
Potassium or Tin.)

So that, in fact, muriatic acid gas is composed of this gas and hydrogen, in equal volumes—is capable of being produced from them, and of being resolved into them.

So that, by these simple operations, we gain the solution of that great problem, which has been so long the opprobrium of chemists—the nature of the muriatic acid gas.

Oxymuriatic gas is not an acid, any more than oxygen; but it becomes acid, like that substance, by combining with inflammable matter.

It is a body belonging to the same class; a peculiar acidifying and solvent principle; determined rapidly from all its combinations, to the positive surface,—and therefore highly negative.

(INSTANCE.
Solution of Salt decomposed by Voltaic Electricity.)

It has been taken for granted in the French theory—and it is stated in every chemical work—that this gas parts with its oxygen with so much facility, that all the combustible bodies decompose it: and it has been stated that charcoal burns in it. All this is error. No known body is capable of decomposing it,—and charcoal has not the least action on it; not even when assisted by the high decomposing powers, and intense igniting agency of voltaic electricity.

(INSTANCE.)

Every body that burns in it, in fact enters into a new combination, from which no oxygen can be procured, except by adding to the mixture bodies that contain it.

(INSTANCE.
Sulphur, Phosphorus, Mercury, &c.)

The mistakes that have arisen on this subject, have depended upon the presence of water.

(INSTANCE.)

Water consists of oxygen and hydrogen; it decomposes most of these compounds.

(INSTANCE.
Phosphoric Sublimate: Water; a strong Acid formed, &c.)

These compounds of oxymuriatic gas enter into combinations with each other; with ammonia, and with various bodies; the elements of which are incapable of decomposing them;—and some of these bodies are possessed of very extraordinary properties.

(INSTANCE.
Compound of Phosphoric Sublimate and Ammonia.)

When oxymuriatic gas is passed into a solution of potash, no gas is liberated.

Potash decomposed.

Nature of hyper-oxymuriate, depends upon its loosely combined oxygen.

Would not this incline one to believe that oxymuriatic gas has an attraction for oxygen? This is really the case.

Mode of procuring the new gas, euchlorine; properties; combustion; colour; weight; explosions explained; singular phenomena of its expansion; solubility in water.

These facts all confirm the views I have given.

Nomenclature.

For Oxymuriatic	Chlorine.
The compound	Euchlorine.
Muriatic acid	Zuthine.

Reasons for adopting these names:—Words should represent things, rather than opinions.

*Theory of Bleaching.**

* * * * *

I have developed, without reserve, all I know on this subject: I am convinced that if the principles I have laid down be attended to, important improvements will result. Errors in theory have been connected with errors in practice; but the progress of truth tends at once to the advancement of the great cause of philosophy—the extension of science—and to the promotion of her practical benefits. No one can say that this subject is matter of mere speculative amusement: and if the cultivation of science adds to the wealth and resources of a country; and if it is pursued in a disinterested way, no one can say that it is an unworthy or undignified object; no one will say that it should be received with coldness, or chilled by indifference. It will never ask for more than it merits; it will always perform as much as it promises.

The vividness of combustion of bodies in chlorine, as compared with that of their combustion in oxygen, might lead to the suspicion that this substance has a stronger attraction for certain inflammable bodies;—and this is really the case.

Potash—Lime—Baryta—all decomposed in this way.

The salts, called muriates of potash and soda, muriates of lime, barytes, &c. are evidently compounds of chlorine with metals; and, what at first view appears a chemical paradox, the substance which formerly was considered as elementary—soda, is in fact more compounded than common salt, which has been always considered as consisting of muriatic acid and soda.

[* Here there were merely brief notes in the original.]

(Proof.
Mr. Murray's Views.—Discovery by my Brother.)

From the analogy of muriate of lime, potash, and common salt, to so many other neutral salts, it might be suspected, that they are similar in their nature—that they may contain acid matter. But, if this is the case, the metals must be compounds of hydrogen with unknown bases: and there are some facts not unfavourable to this speculation; but, it would be absurd to dwell upon them, till there is a greater stock of experiments collected upon the subject. For experiments alone constitute the strength and vitality of our philosophical arrangements; these are things themselves, whereas even the most perfect hypotheses are but as shadows of things.

In making this declaration, it must not be supposed, however, that I am arguing generally against conjectural inferences, or attempting to prove that the imagination ought to be passive in physical research. This would be giving up a noble instrument of discovery; for analogy is in science what the blossom is in vegetation, beautiful and replete with promise, and may ripen into useful fruit. No, I am merely arguing against any premature development of theory, which new observations might prove either to be weak or groundless;—against hasty generalizations, which, pretending only to predict what will hereafter occur, fix, as it were, boundaries to the empire of science, and bring to the standard of a weak or a diseased fancy the august dominion of nature.

The history of the inquiries made, concerning the substance which has been the subject of this lecture, shows the danger of this mode of proceeding.

The confidence of the French inquirers closed for nearly a third of a century this noble path of investigation, which I am convinced will lead to many results of much more importance than those which I have endeavoured to exhibit to you.

Nothing is so fatal to the progress of the human mind as to suppose that our views of science are ultimate; that there are no mysteries in nature; that our triumphs are complete, and that there are no new worlds to conquer.

Those who have fixed the firm foundations of human knowledge—who have most enlarged the boundaries of philosophy—have laboured in the opposite tone of mind, and their characteristic has been humility.

If we take the example of the illustrious man, whose name will be immortalized by the subject of this Lecture, we shall find that he possessed an imagination equally bold and refined, yet made use of hypothesis only as a guide to investigation; and he formed and relinquished his opinions in the truly philosophical spirit, making them, as it were, the machinery for propelling forwards science,—the mere points for employing the lever of experiment.

Mr. Cavendish offers an analogous instance. In his researches, whether minute or grand; whether, investigating the nature of the torpedinal organ, or the charges of electrified jars; or composing water and nitric acid; or weighing the earth;—there is always the same distinction between opinion and fact—the same patience—the same accuracy—the same constant modelling of his own ideas after sensible forms—the same humble submission of hypothesis to experiment.

Conjectural inferences can be useful then only when they are connected with research. Under any other

point of view, they ought not to be received in philosophy; and the more difficult and obscure the subject, the more cautiously we ought to refer to them. Travelling in the night, in a new and uncultivated country, we should be careful what lights we follow; careful not to mistake the ignis fatuus which leads astray, for the lamp which might guide to a place of repose.

It is scarcely possible that any progress should be made in science, without being, sooner or later, of popular utility.* No object of pursuit offers a nobler field for active exertion than experimental research; and it is perhaps no less fitted for these countries, than for this peculiar time and age of the world.

The condition of society, in the different periods of cultivation, may not perhaps be unaptly compared to the different stages of human life. We may be considered, in some measure, as connected with the great nations of antiquity; and we may be compared to them as belonging to a later and more mature age.

In youth, fancy, and imagination, tinge all objects with vivid hues, and connect the external world with their own brilliant images and visions. The periods in which poetry and the fine arts flourished were in the spring-time of cultivation, when all subjects were untouched; when novelty excited curiosity and curiosity was directed by genius; when no difficulties were anticipated, because labour was spontaneous; when there were no models of excellence, except in the forms of living nature, or in the beautiful and sublime ideal creations of the mind.

* [The reflections, in this extract, on the fitness of modern times and of future times for the successful cultivation of science rather than of poetry and the fine arts, occur in a Lecture of 1811.]

The passions and feelings of the human being, and the grand and general features of the external world, are the same in all ages and in all countries. No new organs of sensation or of intellect can arise in the progress of society. That which produced pleasure, or excited emotion in ancient Greece or Rome, will also delight and affect the heart in modern Europe. A standard of excellence in the sublime and the beautiful and the decorous must consequently exist; great original literary works—great works in art cannot be infinitely numerous. The imitator must be inferior to the original. The feeling of the unrivalled greatness of elder times gives to the mind a tone of humiliation: and, though in the more advanced era of cultivation, some productions may rise into popularity from their peculiar excellence, and from their connexion with local circumstances and feelings, or from the novelty of romantic incident; yet the influence of such rivals of the ancient masters will be transient. We may admire for a moment a curious variety of annual flowers, but the perennial rose will for ever delight us.

The case is altogether different in the physical sciences; their progress depends upon minute observation, on patience and on reason; and they are particularly calculated for the more advanced periods of society. In these matters, the ancients were to the moderns but as children to men; their systems were mere collections of words; and, truth was unknown till one great genius broke into pieces the idols raised to represent her, in the confined and dark temples of the schools, and pointed out the external universe as the magnificent shrine in which she was concealed.

There can be no copyists, no imitators in the pursuit of physical science. Nature is inexhaustible; her ob-

jects are boundless. As we can imagine no termination to space, so we can imagine no limit to the combinations and application of matter. Ages may roll on; one theory may succeed another; for these are mutable and partake of the nature of the being by whom they are invented; but facts are eternal: the progression of truth even arises from the destruction of hypotheses, which, in this point of view, as a temporary arrangement, might be compared to the fabled nest of the phœnix, its transient habitation, and by its destruction producing a new and more glorious form.

The love of discovery,* and of intellectual acquirement, may indeed be called an almost instinctive faculty of the mind; but still a combination of circumstances is required to call it into useful exertion. The truly insulated individual can effect little or nothing by his unassisted efforts. It is from minds nourishing their strength in solitude, and exerting that strength in society, that the most important truths have proceeded; and the materials of the magnificent structure of human knowledge, though connected by a few minds, have been furnished by many,—though cemented by unity of genius, they have been produced by diversity of labour.

* * * * * *

In all cases in science, it is our business to analyse every principle, and to ascertain to what expressions of facts it relates, or to what simpler laws it may be referred. It is our duty to separate propositions from human passions, and to reason on them as mere repre-

* [This and the two following paragraphs are from early lectures on the "History of Natural Science," which, I believe, were never delivered, and of which fragments only remain.]

sentations of things; and to employ no terms that are either perplexed, or doubtful, or uncommon. The same processes of thought ever will apply in common life as in science. Experience must be our guide—experience, or moral feeling, founded on accurate and distinct knowledge. Words alone must never be suffered to satisfy or fill the mind, and their relations to facts must be ascertained, before they can be considered either of importance or of use. The imagination must be subjected to the judgment, or rather they must mutually operate, and assist, and correct each other. We may be always safely entertained by wit,—we may be always safely delighted by eloquence,—for they are the life and organs of the mind; but never let us consider wit as argument, or eloquence as truth, till we have coolly examined them by the test of right reason, for this is the only certain guide of opinion; a principle the same in all ages, and in all nations, independent of fashion or caprice—unchanging, immortal.

* * * * * *

The knowledge of the Greeks was generally vague and unsatisfactory, but still it is not possible to avoid admiring the talents and the genius displayed in the construction of their systems. Their failures, in general, may indeed be attributed to their grasping at too much, to too great a consciousness of their extraordinary powers. For the elements of science can only be founded on minute observation; and that high ardour of mind, so essential to the poet, the sculptor, and the painter, is perhaps prejudicial to the philosopher in the first ages of improvement, when facts, not theories, are wanted. In works of the imagination, one mind conceives,—one being executes, and the perfect model is produced in a moment of lofty and enthusiastic

exertion. The structure of science, on the contrary, is a complicated labour of many workmen; diversified materials must be collected, and ages must pass away even before the foundations are laid. Even the refined taste of the Greeks, perhaps, in some measure, opposed the progress of natural philosophy; for in all combinations, it required beauty or perfection, or the highest finish of art. And as no general systems could be founded on real knowledge, the fancy was called in to supply the defect, and an unity was attempted, capable of satisfying the mind, but bearing no relation to the real forms of Nature.

That common air,* nitrous oxide, nitrous gas, and one of the strongest known acids, should consist of two substances united in different proportions, is a fact which, to be convinced of, requires the strongest evidence of experiment.

Nitrous gas, and nitrous acid again, though composed of the same elements, yet are themselves capable of combination, as if they consisted of distinct materials. And these facts, combined with analagous facts relating to the compounds of hydrogen, carbon, and oxygen, render it probable that substances which we at present conceive to consist of different species of matter may ultimately be referred to different proportions of similar species, and in this way the science of the composition of bodies may be materially simplified.

In considering this department of philosophical dis-

* [This extract, comprising in small space the author's conjectures relative to several interesting speculative points, and his opinion on the then imperfect state of chemistry, his expectation of its advance and its future influence on man, judging from its past, is from a chemical Lecture of 1809.]

cussion, it may naturally be asked, Is nitrogen itself an elementary substance? Or is, there a probability of its being a compound?

It is impossible, in the present state of our knowledge, to answer this question decidedly; but the few analogies and facts that we possess on the subject, strongly favour the opinion that it is not a simple body.

Its slight tendencies to combination, its want of inflammability, though its particles possess an entire freedom of motion, the feebleness with which it adheres to oxygen, are circumstances in favour of its containing some of this principle already in combination.

Hydrogen gas, and the gases and fluids consisting principally of pure inflammable matter, possess very high powers in refracting light; the powers of nitrogen on the contrary are low, like those of bodies which contain oxygen.

In addition to the evidence derived from these qualities there are some cases in which nitrogen in combination takes the metallic form.

I am at every moment of leisure pursuing this inquiry, and endeavouring to obtain the basis in a pure state. The only suspicion I can now form is that this basis is hydrogen; but I trust, before the conclusion of this course, to be able to give some distinct information upon the subject.

After oxygen, few substances are of more importance in the economy of nature than nitrogen. Forming so great a part of our atmosphere, it is scarcely possible to conceive that it must not be subservient to other important purposes besides that of merely diluting oxygen gas. It is dissolved in the waters of the sea, of lakes, springs, and rivers. It enters largely into the composition of some vegetables, and of all animals; and it is

extremely probable that great phenomena now obscure, such as the renovation of air, rain, and respiration would be solved by an accurate knowledge of the nature of this gas.

* * * * *

Concerning the aspect of hydrogen and nitrogen, could they be obtained in the solid or fluid form, it is impossible to reason, since there is no probability that we shall be able to condense or compress them into these states; but their elastic form is no proof that their nature is not metallic. Mercury, zinc, and arsenic are all aëriform bodies at the red heat, and at this temperature, as I have found by several experiments they are, like the other gases, non-conductors of electricity. They are in short peculiar species of inflammable air.

If there be, as I ventured to hint at as possible in the last lecture, some one principle of inflammability, then strict analogy would lead us to conclude that there must also be a metallizing principle, some substance common to all the metals. And if such generalizations should be supported by facts, a new, a simple, and a grand philosophy would be the result. From the combination of different quantities of two or three species of ponderable matter, we might conceive all the diversity of material substances to owe their constitution, and as the electrical energies of bodies are capable of being measured, and as these are correspondent to their chemical attractions, so the laws of affinity may be subjected to the forms of the mathematical sciences, and the possible results of new arrangements of matter become the objects of calculation.

From the past progress of the human mind we have a right to reason concerning its future progress. And on this ground a high degree of perfection may be ex-

pected in chemical philosophy. Whoever compares the complication of the systems which have been hitherto adopted, and the multitude, as it were, of insignificant elements, with the usual simplicity and grandeur of nature, will surely not adopt the opinion, that the highest methods of our science are already attained; or that events so harmonious as those of the external world, should depend upon such complex and various combinations of numerous and different materials.

Chemistry, as it has hitherto existed, has been a mere collection of experiments, and perhaps not more advanced in science than astronomy was in the time of Ptolemy, when cycles, and epicycles, and systems of orbits and spheres were assumed to account for the wonderfully uniform revolutions of the heavenly bodies.

Astronomy has been enlightened, has become a branch of mathematical knowledge; so we may expect that chemistry in like manner will be enlightened, and that as the age of the world approaches to maturity, this great branch of philosophy will not want men of sagacity and genius similar to Copernicus, Galileo, Kepler, and Newton, to give to it the elucidations of great discoveries, principles, order, and laws.

It is not merely from the grand perfection of science, but even from every progression of it, that we may look for advantages,—for some more noble views of the external universe, for some applications of the powers of things, for the solution of some of the enigmas of the natural world.

In these respects, chemistry is the most fertile of all the sciences; and the one, even in those ages when it was the least pursued, which produced the greatest benefits for mankind;—the soil bearing the richest harvests, even when least cultivated.

In proof of this, we might go back in a general reference, to the early times in which the working of the metals first ensured the progress of society; and in which men, by using those instruments formed by chemical operations from the rude ore, became the powerful and active masters of the earth. Or, we may fix upon particular instances. A chemical invention in the middle ages saved Europe from desolation by the Saracens,—it was the Greek fire projected from the walls of Constantinople, that checked the progress of the disciples of Mahommed, coming to conquer and destroy in the savage and sensual spirit of their faith. The German monk, who by deflagrating together nitre, and charcoal, and sulphur, discovered gunpowder, did not meanly affect the condition of society, by altering the whole of the art of war, by destroying personal animosity, and by introducing a new moral feeling as well as a new physical power into tactics.

Again, if we look to the superiority of the state of various nations, we shall find that noble chemical inventions have had no small share in exalting their condition.

There is this advantage in investigations relating to the truths of Nature,—that they not only afford sublime pleasure and noble amusement to those who understand the principles on which they are founded; but they furnish happy results and useful combinations for multitudes who are wholly ignorant of their nature and tendency.

This cannot be applied in the same way to many of those pursuits, which, however, likewise exalt and dignify our natures. In the refined arts, in poetry, in painting and in music, knowledge or a cultivated taste are necessary for a full and a happy impression. Neither

the works of Homer, Virgil, Milton, Michael Angelo, or Handel are for the wholly uninitiated; in the experimental arts, on the contrary, the result is obvious, independent of the principle. Thousands have owed a diminution of painful labour to the steam-engine, who are unacquainted with the name even of latent heat, the philosophical truth on which its powers depend. The rudest, the most ignorant mechanic who is wholly uninformed as to the principles of electricity, may erect a conductor and save a building from a thunder storm.

The advances in the transcendental part of chemistry, having as their objects new means of modifying the forms of matter, must lay open practical applications of the highest value, and this kind of knowledge leads to the acquisition of two species of power,—one intellectual, one moral;—one by which a dominion is gained over the properties of things, and by which they are applied to the uses of man;— the other by which the understanding is exalted and enlarged, filled with admiration at the new wonders of creation which are continually unfolded, and impressed with a deeper feeling of the infinite wisdom and power of the Creator.

I cannot pass over this subject,* touching upon a general question of metallic transmutation, without inquiring, were the opinions of the alchemists entirely nugatory? Are the metals certainly simple bodies, and is there no probability of their being generated by other elements?

* [From a Lecture of 1811, in which the author digresses from the impositions of the low alchemists, to the general doctrine of alchemy, and to speculations relative to some element or elements common to all metallic bodies.]

On this subject it is necessary to make some distinctions. With respect to the views of the adepts,—of the alchemists, who pretended to be in possession of the philosopher's stone, there cannot be two opinions. Nothing can be stronger or more just than what Lemery said of these men, "That they professed an art without principle, the beginning of which was deceit, the progress of which was falsehood, and the end beggary." There were, however, enlightened alchemists,—men, who modestly asserted that their means were inadequate to produce effects, which they conceived to take place in the external world. Who, considering the metals as generated beneath the surface of the earth by unknown operations, directed their views towards the discovery of these processes, and had for their highest object the construction of a laboratory in art correspondent to the great laboratory in nature.

In this point of view Helmont was an alchemist; Beecher was an alchemist; Stahl was an alchemist. These men, the fathers of philosophical chemistry, had witnessed the most extraordinary effects of the apparent conversion of metals into each other, even in artificial processes. It acquired considerable labour to prove, that in the precipitation of copper by iron,—it was not an actual transmutation, which certainly is the obvious explanation. There is no physical impossibility in the idea. It appeared even more probable than some facts which have been since discovered.

Even in these times of a more exalted science, after a series of connected discoveries, we have no right to say, that what Stahl suspected—the generation of gold in nature—does not take place. We, it is true, have never seen it composed, or decomposed; but our works are in moments,—those of nature in ages; and, but very

lately, there were many other bodies in the same case, which are now known not to be elementary.

The analogy of the properties of the metals,—their conducting power,—the magnitude of the number representing them,—their splendour,—the similarity of their crystals, would all lead us to the idea of their not being entirely different kinds of matter; but would rather incline one to suppose that they contain some common element or elements. There is likewise an experiment favourable to this idea, in which gaseous matter,—compound gaseous matter,—assumes the metallic form.

(*Ammonia.*)

A series of proportions may be formed in which the metals may be supposed composed of hydrogen, and another substance in definite quantities; and, in this hypothesis, the lightest would contain the largest quantity of hydrogen, and possess as they are found to possess, the strongest attraction for oxygen and chlorine. There is not now time to develop this idea, nor indeed would it be fitted for an experimental Lecture.

[The author adds.] It will be useless to speculate upon the consequences of such an advancement in chemistry as that of the decomposition and composition of the metals. At this era of paper circulation, we should have no reason to dread any dangerous effects from the manufacture of gold: nor would our legislative bodies, I conceive, adopt the same plan as the Lords and Commons in the fourteenth century in the time of the regency, who then passed an act against the multiplying of gold,—under the fear that if the government of that period should obtain possession of the method, it might become despotic, and be above asking any pecuniary aid of the people! One wonders equally at the want of philosophy and common sense in that age; and

we must glory in the comparison of past with present times.

I hope I shall not be misunderstood on this delicate subject, or from what I have said be considered as an alchemical projector.

It is the duty of a chemist to be bold in pursuit. He must not consider things as impracticable, merely because they have not yet been effected. He must not regard them as unreasonable because they do not coincide with popular opinion. He must recollect, how contrary knowledge sometimes is to what appears to be experience. Our senses seem to prove to us, that the earth is a plain surface and at rest;—our science informs us that it is round and revolves.

Whoever pursues experiment, with the view of discovering truth, however much he may mistake his means and talents, yet will still be moving in a useful path.

To search for the elixir of life, or the powder of projection, would be a mark of a feeble, prejudiced and ignorant mind. But to inquire whether the metals be capable of being decomposed and composed is a grand object of true philosophy.

Of the numerous mysterious practices supposed to be connected with the discovery of mines, almost the only relict is, the search by the divining rod;* and the

* [From a Lecture on metallic veins, the fourth of the course, which the author gave in 1811.

This extract on the divining rod, in which reason is strongly opposed to superstition, and an explanation is given well adapted to convince the most credulous in the effects of the hazle twig, that it possesses none of the virtues attributed to it, is from a Lecture on metallic veins delivered in 1811.]

belief in this is rapidly going out of fashion, even amongst the common miners. The divining rod is a forked stick of hazel, which, when held horizontally, a branch being in each hand, was supposed to be attracted by metals. Most of the ancient writers on metallurgy have given long theories to account for the efficacy of the rod,—and even as late as 1778, Mr. Pryce, in his "History of the Cornish mines," states his full belief in its powers; and explains them by supposing that certain steams or vapours rise from mines; though he does not make it very clear, why the hazle, and no other substance, should have such a particular affection for these effluvia. The divining rod, it is well known, is applied to the discovery of springs of water, as well as of metallic veins; and, there are very respectable and excellent persons, who believe in this power, and that they themselves are capable of exercising it.

Nothing should be disbelieved because it is marvellous, because it does not coincide with our received opinions. The business of philosophy is to investigate causes. A few years ago, the fall of stones from above, appeared a mere fable; yet accurate observation has confirmed the fact by a collection of testimonies, that it is impossible for a candid mind to question. A very few observations will be sufficient to enlighten this subject of the divining rod, and to show what is possible, and what must of necessity be unfounded.

There are persons so susceptible of electrical impressions as to be affected by the approach of a thunderstorm with peculiar unpleasant sensations, or even by the excitement of a common machine. And, large masses of metallic substances, and a moist stratum of earth, being conductors of electricity, will necessarily influence the electrical state of the atmosphere, and may

produce an effect on very delicate nerves, — possibly a peculiar sensation on the surface of the skin. But the bending of the hazel twig can only be produced by the muscular power of the hands. The inert vegetable fibres cannot be made to twist round, either by weak electricity, or moisture, or metallic steams. This effect is merely connected either with a real or an imaginary impression on the nerves, which might be as easily associated with the twisting of the fingers, or the closing of the eye-lids, or any other arbitrary muscular motion. Again, there is generally a false idea with respect to the manner in which water exists below the surface. It is vulgarly supposed that it fills cavities in the earth; whereas in all common cases, it is merely distributed through a stratum of gravel, sand, or clay; there is no collection of water, till an excavation is made; and though the central part of the moist stratum is the part where the water would most readily collect, yet water would likewise flow into any cavity made in any part of the stratum, so that the idea of selecting a particular limited spot for water is absurd; and at a certain depth below the surface, water may always be found. A vein or mass of metal is much more definite and limited; yet the divining rod usually fails applied to this mode of discovery; and if there be sensations connected with the electrical effects of conductors below the surface, they must be of a very uncertain kind, and foreign influences, particularly those of atmospherical changes, must materially interfere with them. There was, a very few years ago, a Saxon adventurer, who travelled through England, professing to be able to discover precious ores by the hazel. He deceived and deluded several credulous people; and left the country with a considerable sum of money — which I believe was the only way

in which he proved the existence of the attraction between his rod and the precious metals.

I trust that what I have said will not offend the feelings of any individual. To remove erroneous ideas, and to discover truths, is equally an object of science. Prejudices and false opinions respecting the powers of nature, are not merely baneful in their relations to philosophy, but likewise in their common effects upon the mind. Its dignity and its highest tone of feeling depend upon truth; one false idea leads to another; every exercise of the reason strengthens the habit of correct thinking, and adds something to the influence and power of common sense.

The great forms of matter,* in the external world, are constantly impressing themselves upon our senses, and a very superficial observation only is necessary for their classification.

A solid body of land, which constitutes a large part of the globe, and which is comparatively permanent in its forms, fixed and immoveable; a great expanse of waters, the surface of which is in continued motion; and, an atmosphere constantly made evident to us by the winds which agitate it, or the clouds and vapours which it supports, give sufficient evidence of the existence of three distinct states of matter. Besides these, there are phenomena which depend upon the sun and heavenly bodies; and the effects of light and heat, it is well known, are connected with their presence.

Solids, fluids, elastic fluids or gases, and radiant or

* [This extract on the great forms and active powers of nature is from a chemical lecture of 1812 and from the last course which the author delivered in the theatre of the Royal Institution.]

etherial substances, constitute the great classes of natural bodies, which, by their operations and changes, produce the phenomena of chemistry.

Of solids, the varieties are almost infinite,—metals, inflammable substances, stones, earths, gems, animal and vegetable productions,—forms, the analogies of which have constituted distinct sciences, the provinces of the natural historian, the botanist, the mineralogist,—are included in this comprehensive class of natural bodies.

Fluids are less numerous; but water, mercury, oils, spirits, the juices of plants, and animals, present a sufficient diversity to confuse the mind not assisted by philosophical views.

Of gases, the varieties are still fewer. They are not contemplated in nature, and most of them are productions of modern chemistry. They are all transparent; but they differ in density, some in colour, and decidedly in their properties.

These three classes of bodies, I stated in the Introductory Lecture, are all capable of being weighed and measured, and their alterations estimated by correct experiments. But the fourth class, radiant matter, cannot be submitted to the same tests, and its powers and nature can only be judged of by its effects.

The sensations of vision are produced on the eye,—those of heat on the organs of feeling, by matter in motion,—and it is either impelled by, or emitted from the heavenly bodies; but whether there are many distinct species, or one subtile fluid under different modifications,—or whether the particles of any kind of matter, in rapid motion, are capable of producing the phenomena, are subjects for discussion. And, besides heat and light, radiant matter produces other effects, intimately connected with the phenomena of chemistry.

This paper was covered yesterday with a substance named horn-silver; half of it was exposed to daylight; the other half was preserved in darkness; one is black, the other unaltered. At first it might be supposed that the same matter, or impulse from the sun, which causes light, produces likewise this phenomenon: but it is not so; if a beam of the sun be admitted through a hole in a dark room, it will produce a coloured image, and a piece of prepared paper exposed to the beam will be affected where there is no visible light.

There may be other influences, as yet undiscovered, exerted by rays from the celestial bodies,—or from substances on the surface of the earth. A few years only are passed since we have become acquainted with the varieties of gaseous bodies; and, still more refined methods are required for operating upon these subtile moving substances, which are not peculiar to our planet, and which do, as it were, connect us with the great system of the universe.

To be able to understand the permanency or the changes of forms of bodies, the series of events in the history of Nature, and in the operations of art, it is necessary, as I mentioned in the Introductory Lecture, to consider the active powers belonging to matter, and the laws of their operation.

By active powers are understood those powers which cannot be separated from the bodies which they affect, and which produce the motions of their particles,—such as the expansive energy or the power of repulsion which produces heat, and attraction in its different modifications,—as gravitative, chemical, or as electrical attraction.

Active powers must be considered as belonging to matter; but it is not necessary to suppose them inherent in

it. It may be regarded itself as inert; and all effects produced upon it as flowing from the same original Cause, which, as it is intelligent, must be divine.

The same power of gravitation which produces the revolutions of the planets round the sun, and preserves the fixed stars in their places, combined with another cause, is essential to the regular succession of the seasons and the changes of temperature so necessary in the system of the globe.

The different powers in nature, so harmoniously co-operating, must be referred to one source. When we perceive a great and magnificent building, we know that it must have been the result of the labours of various hands; but we are secure that the perfect design by which its parts have been arranged must have been the combination of a single mind.

Scheele called this elastic fluid [oxygen] empyreal air, fire-air, from the vividness with which it supported flame.* Dr. Priestley named it dephlogisticated air, from an idea that it had a particular tendency to absorb or unite with a principle imagined by all chemists to exist in combustible bodies, and which was called phlogiston.

The knowledge of so singular and interesting a body as fire-air or oxygen, could not fail to elucidate the whole philosophy of chemistry, and to throw particular light upon the nature of combustion.

The alchemists considered fire as a peculiar specific element combined with bodies, as having originally

* [This and the following passages relative to oxygen and the doctrines of different schools of chemistry, are from a lecture of 1811.]

emanated from the sun, and a kind of vivifying power in the terrestrial world.

The first philosopher who reasoned in the spirit of the Baconian school upon the phenomena of fire, was Robert Hooke. This celebrated person in his Micrographia, has given an admirable hypothesis on this subject. Combustion, says he, is nothing more than a solution of the burning body in a part of the air, analogous to the solution of a metal in aqua fortis; and the heat and light are the result of this kind of action.

Mayow;—nitro-aërial spirit.

Beccher, a contemporary of Hooke, an admirable operative chemist, but a little tinctured with the views of alchemy, advanced a different idea. There is, said this person, a peculiar light substance, capable of becoming or producing fire, which may be called phlogiston, and this adheres in all combustible bodies, and is dissipated during their inflammation.

This doctrine of Beccher was espoused by his disciple Stahl, and defended with great talent, who conceived that he had demonstrated the truth of the opinion of his master by a decisive experiment.

Sulphur in burning produces a peculiar acid.

(INSTANCE.)

Now, Stahl said, sulphur consists of an acid united to phlogiston; the phlogiston is dissipated in burning, the acid remains; and by heating the acid with charcoal, the charcoal disappears and the phlogiston is restored to the sulphur.

This is an excellent specimen of the nature of the chemical reasoning of the age. Stahl neither proved that the weight of the sulphur was greater than that of the acid, nor that the weight of the charcoal was added

to that of the acid. And yet, though Boyle advanced an opinion of the same kind as that of Hooke, and defended it by a very happy train of reasoning, and by his admirable experiments upon the air-pump; yet, the notion of Stahl became the established doctrine of the whole of Europe. The influence of the atmosphere was altogether neglected in the phlogistic school of chemistry: but, the discovery of an elastic fluid, which so wonderfully supported combustion, necessarily drew the attention of philosophers to this important circumstance.

Boyle had shewn that different preparations of phosphorus, which he named aërial noctiluca, would not burn in the space above mercury in the Torricellian vacuum, where there was no air; but that the minutest quantity of that elastic fluid rendered it luminous.

(INSTANCE.)

Dr. Priestley, adopting the idea of Stahl, conceived that the air acted by a kind of attraction for phlogiston, that by means of it, phlogiston was as it were drawn out of the burning body. And assuming the idea that his new gas was entirely free from phlogiston, and therefore had a much stronger attraction for it than air, he adopted the term for it, to which I have just now referred,—the term of dephlogisticated air.

It had been observed by some of the alchemists, particularly Taverinus and Libavius that tin and lead increased in weight when exposed to heat, during their slow combustion, and John Rey, a physician at Bezers, referred these phenomena to the fixation of air in the metal. This acute man has been represented as the discoverer of the fact of the increase of weight of tin and lead during calcination; but whoever will refer

to his book, published in 1630, will find that he merely reasons upon facts observed by others; and in a light and playful way laughs at the alchemical school; but without attaching any importance to his own ideas. His work is a mere logical exercise in physical science.

When metals were burnt by means of oxygen gas, an increase of weight was found uniformly to result.

(INSTANCE.)

But how could this happen if they lost phlogiston?

Some speculative inquirers said, phlogiston differs from all other bodies in nature. It is a principle of absolute levity. It actually renders bodies lighter by uniting to them.

But this vague idea was embraced by very few philosophers. It was opposed by the analogy of nature; by the whole series of physical reasonings, and was contradicted by some very simple facts.

Charcoal converts sulphuric acid into sulphur, and there is a loss of weight. The disciples of Stahl supposed charcoal to be pure phlogiston; therefore charcoal should have no weight, which is known to be absurd. And, Mr. Cavendish ascertained that charcoal burnt in oxygen, produced carbonic acid, weighing exactly as much as the charcoal and oxygen consumed.

(INSTANCE.)

I have mentioned that this illustrious philosopher discovered inflammable air, since called hydrogen, and as it was given off during the solution of metals in certain acids; this light and combustible principle was considered by many inquirers as the true phlogiston, and it was conceived that in all cases of combustion, the inflammable air united to oxygen, and that both remained

in the new compound; and, when Mr. Cavendish discovered that water might be composed from the combustion of oxygen and hydrogen, — then, the most enlightened inquirers of the phlogistic school conceived that water was formed in all cases of combustion, which adhered to the burning body.

Lavoisier.—Dr. Black.

Mr. Higgins.—A long and violent controversy.

This idea of the light and heat coming from the oxygen gas is opposed, &c.—by nitre.

These views depend upon the circumstance that our atmosphere contains oxygen; but in an atmosphere composed of inflammable matter, the bodies containing oxygen would appear as the combustible body.

(INSTANCE.
Hydrogen gas.—Oxygen gas.)

Argument against the Lavoisierean theory, from the light given out in the combustion of phosphorus, and not in the slow combustion of iron.

This will not agree with the light being evolved by the burning body: for when phosphorus is converted in nitric acid into phosphoric acid, there is no light.

The simple theory is, that light and heat are the result of chemical attraction—of bodies, naturally positive and negative; charcoal burns brilliantly in oxygen; but potassium burns in carbonic acid; and this agrees with the notion, that I have ventured to bring forward.

But, it will be asked, are not heat and light matters specific in their nature, and must they not be combined with the acting bodies?

To this the reply is obvious. Radiant light and heat are matter moving in free space; but it may well be

doubted whether they are specific and peculiar kinds of matter.

The opinions of Boyle and Hooke respecting heat of combustion were not very different from those I have advanced, and have an analogy to those of Newton; and Mr. Cavendish, throughout his life, maintained a similar doctrine, as I have often learnt from his conversation.

As I said on a former occasion I do not mean to defend opinions by sheltering them under illustrious names; but I may at least be permitted to observe, — and it is no small pleasure after the lapse of a century of investigation and of wonderful improvement in science to find,—that the views of our illustrious countrymen are still the most probable that have been advanced, and offer the strongest proof of their sagacity and genius.

It cannot impair the glory of later inquirers, that of doing justice to the merits of early discoveries; and, on this occasion, it is impossible to be just, without being national. We have, perhaps, in these countries too much neglected the glorious memory of our philosophers. A French school of chemistry is constantly talked of; the German school of chemistry is continually quoted; but the British school of chemistry seems an unknown word. Yet pneumatic chemical philosophy as peculiarly belongs to this country, as metallurgical chemistry to Sweden and Saxony. A most brilliant light long shone forth in this island; but it was little attended to, till it was reflected from France, and newly modified, tinged with novel colours. Our scientific possessions were quietly given up; and, the influence of a series of opinions, which daily experience is showing to be in great part unfounded, was made predominant by the

cumbrous shackles of a new language, formed rather after the presumptuous idea of a perfect and permanent state of science, than with any humble views towards its extension and progression.

The whole series of discussions that have been brought forward upon the fire-air, prove that it is a body very prone to enter into combination, and with great energy, and usually producing light, and always heat. The compounds that it forms differ according to the nature of the body with which it combines. Thus with hydrogen it forms a neutral compound,—with sulphur a strong acid,—with potassium a corroding alkali, —with iron an insoluble tasteless body, and with certain metals it forms earths. Oxygen, therefore, or the producer of acid is a very improper name for it; for there are very powerful acids that do not contain it, and it exists in the most energetic alkalies. It might be called with more propriety hydrogen, the producer of water, or alkaligen or geogen; but all these names are equally exceptionable. At present, it is better to continue the name of oxygen, and to wait for a more mature period of the science for a reform of the nomenclature.

I mentioned in the introductory lecture, that whenever electrified surfaces from the voltaic apparatus were made to act upon water, oxygen is produced at the positive surface, and hydrogen at the negative, and exactly in the same quantities as are required to form water by their combustion.

(INSTANCE.
2 *of hydrogen*, 1 *of oxygen.*)

If we compare their relative weights, the weight of hydrogen will be 1, that of oxygen 7·5; and if these weights be symbols of attractive powers, then the + elec-

tricity of that of 1 of hydrogen will balance the — electricity of that of 7·5 of oxygen.

It is a very important circumstance, and there will be many opportunities for illustrating it, that wherever oxygen enters into combination, it is in a proportion that may be expressed by this number, or of some multiple of it, that is either 7·5, 15, 22·5, 30, and so on.

I referred in the introductory lecture to the atomic hypothesis, which I am far from being disposed to adopt. I am much more inclined to believe that definite proportions will be found to depend upon the identity of the matters really acting upon each other; and that the true solution of this most important part of philosophy will be found in a great simplification of elementary materials. But the discussion of this doctrine properly belongs to a more advanced part of the course, when it will be seen that chemistry is rapidly advancing towards the state of a science, in which results may be predicted, and of which the laws will be found equally simple and invariable.

I have already referred to the analogy between the heat and light produced during electrical action, and that generated by chemical action: * and that the effects corresponded, is an argument in favour of an identity of cause.

According to the degree of electrical action the heat is intense.

(INSTANCE.)

The case is the same in chemical action.

(*Sugar,—Oxymuriatic acid.*)

* [Of the four extracts which are given relative to heat, the first is from a Lecture of 1809, the two next from Lectures of 1810, and the last from one of 1812.]

In a former lecture, I stated some ideas with respect to the hypothesis of the general relations of heat.

One notion was, that heat might be generated or composed of the two electricities.

The other, that it might be merely the result of an approximation of the parts of bodies, whether produced by mechanical, chemical, or electrical causes.

The general solution of this great problem must depend upon the distinct knowledge of heat, light, electricity, and chemical attraction;—whether these effects are produced by peculiar subtile matters; or whether they are qualities capable of being generated in, or communicated to every species of body.

Without entering minutely upon this inquiry, I shall mention some circumstances which appear to bear immediately upon the general subject of this description, and which may afford considerable illustration of what is, perhaps, the most mysterious part of physical science.

In the Voltaic battery with large plates, the wires of platina seemed capable of being preserved in constant ignition.

In the last lecture, you saw this ignition kept up only for a minute. I have since witnessed the effect for many minutes.

You shall again judge for yourselves, whether it does not appear to be constant.

(INSTANCE.)

Now, if this heat were owing merely to an approximation of the particles of the platina, these particles must immediately gain their extreme point of union, and the effect could not be permanent.

Or, if heat be considered as a fluid, pressed out by

the two electricities from the pores of the metal, the quantity must be limited.

The ignition, likewise, is independent of air; it takes place in a vacuum.

(INSTANCE.)

It cannot be said, then, that the heat is attracted from air, and given out by the metals.

If heat be material, it is either generated by, or composed of the two electricities. Or, if the two electricities be merely exhibitions of the natural attractive powers of matter, then heat must likewise be considered as a quality; and the supposition of Bacon of its being motion, must be preferred to that of Stahl, of its being a subtile and etherial matter.

It is not a little singular that you have witnessed the development of an hypothesis in one lecture, and have seen it confuted with a fact and rejected in another lecture.

Terrestrial heat can no longer fairly be considered as an universal effect of the approximation or condensation of matter.

The only use of an hypothesis is, that it should lead to experiments; that it should be a guide to facts. In this application, conjectures are always of use. The destruction of an error hardly ever takes place without the discovery of truth.

Upon all occasions, when I venture upon a conjecture, you will, I trust, have the goodness to consider it as brought forward in the same spirit,—not as an opinion which it would be painful to relinquish, but as a hint which may lead to inquiry. Indeed, speculation, I conceive, should always be regarded in this point of view. And, except when it has its source in facts, and its termination in experiments, ought to be rejected as dangerous and unprofitable.

Hypothesis should be considered merely an intellectual instrument of discovery, which at any time may be relinquished for a better instrument. It should never be spoken of as truth, its highest praise is verisimility.

To be attracted to mere speculation, is to be directed by a dream. Knowledge can only be acquired by the senses. Nature has no archetype in the human imagination. Her empire is given only to industry and action, and governed by experience.

These experiments, [made with the great battery of 2000 plates, shewing the fusion of the most refractory metals,] as well as those which I have before exhibited, do away the opinion, which many able writers have supported, of a cold fusion by electricity; a notion which has been lately revived by M. Berthollet. It cannot be said that the electricity merely increases the oxidability of the metals, and thus produces their combustion; for the phenomenon takes place, with even more energy in vacuo, if platina wire be used.

[Having shown this experiment of intense ignition of platina wire in a vacuum, the author made the following commentaries on it. On this fire, where there was "no atmosphere, and a perfect insulation," he says:—]

The fact is the strongest one that I am acquainted with, against the notion of heat being a peculiar subtile fluid, which cannot appear, unless given off from some combustible. The air cannot give it, for there is none. Let it be said to be composed of the two electricities; *i. e.* let them be regarded as different subtile fluids; but, in this case, cold ought to be produced in some part of the system. I once had this idea. It satisfies the imagination, but not the reason. If we suppose one fluid, and this fluid carries heat with it, whence can its heat be derived? If we conceive it to be heat or light,

why should it be resolved into heat or light the moment that it is strongly attracted by matter? Let the heat be said to be pressed out from the metal; but then there must be an equilibrium. No theory is consistent but that of heat being matter in a state of motion; and of electrical change being successions of attractions and repulsions, producing these motions. But, it is said, there must be matter; true: but the question is, whether this is specific? whether different kinds of matter, when projected into free space, may not become heat? The notion argued against is one simple, specific, indestructible fluid of heat. There are a great variety of gases: suppose the particles of hydrogen could be made to pass through free space; they would, perhaps, be heat, suppose them to expand as much.

The particles producing terrestrial heat, seem different from those producing solar heat: so of light.

Vulgar idea—like that of the peasant, every thing done by a spring; so every thing must be done by a fluid. The ether was the ancient fluid; then there was a phlogistic fluid: we have had the magnetic fluid, the vitreous fluid, the resinous fluid; and within the last few years there has been a fluid of sounds; and, in a book, which I lately received from France, published by M. Azais, all the phenomena of nature are explained by a gravic fluid.

But it is said that nothing but matter can pass through bodies, and that therefore there must be some fluid concerned—a strong argument in the perforation of a card, by the discharge of an electric battery, exhibiting a burr on both sides; but if something absolutely passed through, the burr could only be on one side, unless there are two fluids created in the middle of the paper, one of which passes one way, and the other another way. On the

idea which I have ventured to form, both the interior and the exterior of the paper are violently attracted, and will be separated; one towards the positive side of the jar, the other towards the negative.

The phenomena of the mechanical excitation of heat, are the principal circumstances that have led to the adoption of the opinion of Bacon and Newton, that heat is motion. The new and extraordinary views that have been thrown upon these subjects by late investigators, though, on the first glance, they appear opposed to the Baconian idea, yet they may be easily reconciled to it. The invisible heat-making rays in the solar beam, we know to be matter in motion; and this matter may communicate expansive motions to the particles of terrestrial bodies; and the particles of common bodies, when thrown off and moving through free space, may possibly, according to the hypothesis of Newton, constitute heat and light.

We know that solids, by a certain increase of temperature, *i. e.* of repulsive power, become fluids; and that fluids, by a still higher repellent motion of their particles, can occupy a space some hundred of times greater, and become gases;—and, if particles of gases were made to move in free space with an almost infinitely great velocity—*i. e.* to become radiant matter, they might produce the different species of rays, so distinguished by their peculiar effects.

A platina wire may be kept white-hot by voltaic electricity, for an indefinite time in vacuo. If the Newtonian hypothesis be true, it ought to lose weight by ignition.

This would be an experimentum crucis, or experiment of demonstration respecting the two doctrines—(*i. e.*

whether heat be a substance, *sui generis*, or any kind of matter in violent motion.)

[He adds] It is a particularly happy circumstance of the present era of philosophical inquiry, that we are in possession of powerful instruments, having numerous applications to all the more recondite departments of the science of nature; and that there are enigmas not yet solved, ought only to be a stimulus to our industry; for the solution of these enigmas cannot fail to simplify our systems—to place new powers within our reach—and to substitute single and consistent theories for multiplied and vague hypotheses.

I do not think we have at present any means of deciding upon this question of the nature of heat; and its effects may be studied,—and it may be employed as an instrument of experiment, without the necessity of adopting any hypothetical views respecting its cause. It is my intention merely to give a caution with respect to the adoption of the chemical solution,—which is by far the most generally received. Indeed, the matter of heat or caloric is sometimes talked of with the same confidence as water, or any common ponderable bodies. It is of great importance to the progress of science, that facts should be separated from what is imagined; that the nature of our knowledge, and the grounds of our opinions, should be strictly defined. The truly philosophical inquirer into nature will not consider it as a disgrace, that he is unable to explain every thing; he will wait, and labour with hope, tempered by humility, for the progress of discovery;—and he will feel that truth is more promoted by the minute and accurate examination of a few objects, than by any premature attempts at grand and universal theories.

I make these confessions of ignorance, [to solve certain problems in electro-chemical science,] rather with a feeling of pleasure and of hope, than of uneasiness and humiliation.* Insulated, striking, but unexplained facts in science, are to the philosopher what green branches and fruits in the ocean are to the mariner voyaging for discovery; they are omens of land, which, even though he himself should not have the felicity of attaining, he may yet indicate to others.

I hardly know which we ought most to rejoice at — the progress that has been made in natural knowledge, or the progress that is to be made. If a limit could be obtained, if we could rest satisfied with what is known, how great a source of activity, profit, and pleasure, would be destroyed! And we cannot be too grateful for that wonderful constitution of the external universe, by which it is rendered an inexhaustible source of interest to the inexhaustible human mind; by which it is so admirably adapted to keep awake that happy curiosity, which is a constant germ of improvement; that noble kind of ambition which continually tends to exalt the intellectual being; that flame of life, unquenchable even in the fountains of knowledge.

It is a great matter that we should put no improper confidence in any notion or doctrine. Doubt in physical research is highly salutary, and is always the parent of inquiry, and often of truth. Though our reasonings may have the perfect character of verisimility as applied to known objects, yet we have no right to say that our view is an ultimate one; our

* [This extract on the fitness of science to the human mind; and the following, on the beneficial effect of doubt on science, are from a Lecture of 1809.]

system of logic cannot unfold all the resources of nature. The maxim of a chemical investigator should be that adopted in the motto of an illustrious society—"To rely on the word of no master." Nothing has so much checked the progress of philosophy as the confidence of teachers in delivering dogmas as truths which it would be presumptuous to question. It was this spirit which, for more than ten centuries, made the crude physics of Aristotle the natural philosophy of the whole of Europe. It was this spirit which produced the imprisonment of the elder Bacon, and the recantation of Galileo. It is this spirit, notwithstanding the example of the second Bacon, assisted by his reproof, his genius and his influence, which has, even in later times, attached men to imaginary systems, to mere abstracted combinations of words, rather than to the visible and living world, and which has often induced them to delight more in brilliant dreams than in beautiful and grand realities.

In the early stages of discovery the imagination is often dazzled by the brilliancy of the new facts, and trusts to weak or remote analogies.* The whole language of nature informs us, that in animated beings there is something above our powers of investigation; something which employs, combines, and arranges the gross elements of matter,—a spark of celestial fire, by which life is kindled and preserved, and which, if even the instruments it employs are indestructible in their essence, must itself, of necessity, be immortal.

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* [From a Lecture on electro-chemical science; the remark in this paragraph was made by the author, alluding to some wild speculations, in which irritability and even sensibility were referred by the early inquirers to electrical powers.]

In the investigation of geology, as in almost all other inquiries to which the human mind has been ardently devoted, very few speculations have indeed been formed, not possessed of some immediate or remote applications to the real progress of science.* The understanding is permanently guided by experience; and brilliant delusions, even though consecrated by the efforts of genius, cannot very long continue to deceive the public. Useful truths are often ascertained in the attempts made to detect imposing errors; and the appeal to experiment, which is the last and the only certain test of the merits of opinion, can hardly fail to lead to discovery. Hypothesis uniformly produces discussion; and the more ingenious, and the more active the talents by which it was formed, the greater is the probability of a minute and serious examination of facts. To explain nature, and the laws instituted by the Author of nature, and to apply the phenomena presented in the external world to useful purposes, are the great ends of physical investigation; and these ends can only be obtained by the exertion of all the faculties of the mind; and the imagination, the memory, and the reason, are perhaps equally essential to the development of great and important truths.

In this room,* I am sure, I need not enter into any elaborate arguments in favour of a certain acquaintance with the philosophy of nature, in the system of improvement of the female mind. The same reasoning would, I conceive, apply, in this case, as to the study of the ma-

* [This extract on the cultivation of the sciences is from a geological Lecture.]

† [The theatre of the Dublin Society; the extract is from a Lecture delivered there in 1811.]

thematics, as a part of the education of the other sex. By accustoming the mind to strict reasoning, and minute observation as to matters of fact, the judgment is strengthened, and rendered more acute and distinct in its application to common affairs. Unhealthy sensibilities are destroyed, and the imagination refined and exalted. It has been too much the custom to endeavour to attach ridicule to the literary and scientific acquisitions of women. The fashionable education is principally directed to those accomplishments which please only in that season of youth, which, in itself, is full of fascinations; whilst it neglects the more solid endowments, which give a dignity and a charm to the advanced periods of life, and which, independent of external advantages, are exalted and rendered delightful by time. In a very popular work, Milton is quoted against the literary and scientific acquisitions of women; but the instance is an unhappy one; for this great man, most illustrious as a poet, unfortunately was not distinguished either for his respect, his attention, or his attachment to the softer sex; and yet, notwithstanding this, he has made the chief pleasure of the primeval paradise to consist in the study and admiration of the wonders of nature, as if conscious of their fitness for the best condition of our being. The standard of the consideration and importance of females in society is, I believe, likewise the standard of civilisation. The leisure of the higher classes is so great, their influence so strong, that it is almost their duty to endeavour to awaken and keep alive the love of improvement. It is only ignorance or selfishness which can wish to prevent the diffusion of knowledge. It is the grand privilege of human nature; it is the lamp which guides our steps amidst the obscurity of things, which preserves the mind awake to its

just interests, carrying it from transient and trifling objects to those which are permanent and useful; affording a noble employment in youth, a delightful consolation in age; teaching, that in all things there is order, and harmony, and wisdom; exalting the sensual into the intellectual, and the intellectual into the moral and religious being.

In a former course of lectures I adverted to the circumstances which led to the proposals for constructing the new apparatus.* I cannot avoid referring to them a second time; my inclination, my feelings, my duty render this necessary.

In a great country like this, it was to be expected that a fund could not long be wanting for pursuing or perfecting any great scientific object. But the promptitude with which the subscription filled was so great, as to leave no opportunity to many zealous patrons of science for showing their liberality. The munificence of a few individuals has afforded means more ample and magnificent than those furnished by the government of a rival nation; and I believe we have preceded them in the application of the means. In this kind of emulation, our superiority, I trust, will never be lost; and I trust that the activity belonging to our sciences will always flow from the voluntary efforts of individuals,

* [This extract is from an introductory lecture to a course on electro-chemical science, delivered in 1809, when a fund had been formed by subscription to construct a great voltaic battery of 2000 double plates, which was soon afterwards completed; a description of which and of its effects is to be found in the fourth volume, page 110. By some authors who have not paid attention to the progress of electro-chemical research, it has been erroneously supposed and asserted that the decomposition of the fixed alkalies was first effected by this great battery.]

from whom the support will be an honour—to whom it will be honourable.

In commenting upon the noble spirit by which this object has been effected, I trust the general state of this institution will be a reason why I should press still further the use and the necessity of patronizing and promoting the objects of establishments connected with the progress of discovery, and the diffusion of experimental knowledge. This department of inquiry demands an apparatus which it is in the power of few individuals to provide. It is connected with considerable expense; and, though it may produce great public benefits, cannot, when carried on in the true spirit of philosophy, be a source of private gain.

Without facilities for pursuing his object, the greatest genius in experimental research may live and die useless and unknown. Talents of this kind cannot, like talents for literature and the fine arts, call forth attention and respect. They can neither give popularity to the names of patrons, nor ornament their houses. They are limited in their effects, which are directed towards the immutable interests of society. They cannot be made subservient to fashion or caprice; they must for ever be attached to truth, and belong to nature. If we merely consider instruction in physical science, this even requires an expensive apparatus to be efficient; for without proper ocular demonstrations, all lectures must be unavailing, — things rather than words should be made the objects of study. A certain knowledge of the beings and substances surrounding us must be felt as a want by every cultivated mind. It is a want which no activity of thought, no books, no course of reading or conversation, can supply. That a spirit for promoting experimental science is not wanting in the country, is

proved by the statement which I have just made, by the foundation in which I have the honour of addressing you, and by the number of institutions rising in different parts of the metropolis and in the provinces. But it is clear that this laudable spirit may produce little effect from want of a just direction. To divide and to separate the sources of scientific interest, is to destroy all their just effect. To attempt, with insufficient means, to support philosophy, is merely to humiliate her and render her an object of derision. Those who establish foundations for teaching the sciences ought, at least, to understand their dignity. To connect pecuniary speculation, or commercial advantages, with schemes for promoting the progress of knowledge, is to take crops without employing manure; is to create sterility, and destroy improvement. A scientific institution ought no more to be made an object of profit than an hospital, or a charitable establishment. Intellectual wants are at least as worthy of support as corporeal wants, and they ought to be provided for with the same feeling of nobleness and liberality. The language expected by the members of a scientific body from the directors ought not to be, "We have increased your property, we have raised the value of your shares." It ought rather to be, "We have endeavoured to apply your funds to useful purposes, to promote the diffusion of science, to encourage discovery, and to exalt the scientific glory of your country."

What this Institution has done, it would ill become a person in my place to detail; but that it has tended to the progress of knowledge and invention, will not, I believe, be questioned. Compare the expenditure with the advantages. It would not support the least of your public amusements; and the income of an establish-

ment, which, in its effects, may be said to be national, is derived from annual subscriptions scarcely greater than those which a learned professor of Edinburgh obtains from a single class.

With more ample support, more, undoubtedly, would be effected. With a devotion to the experimental sciences and arts, nothing but good could result from an extension of the undertaking: and it is no mean object to the country, that the first attempt of this kind should succeed.

The progression of physical science is much more connected with your prosperity than is usually imagined. You owe to experimental philosophy some of the most important and peculiar of your advantages. It is not by foreign conquests chiefly that you are become great, but by a conquest of nature in your own country. It is not so much by colonization that you have attained your pre-eminence or wealth, but by the cultivation of the riches of your own soil. Why, at this moment, are you able to supply the world with a thousand articles of iron and steel necessary for the purposes of life? It is by arts derived from chemistry and mechanics, and founded purely upon experiments. Why is the steam-engine now carrying on operations which formerly employed, in painful and humiliating labour, thousands of our robust peasantry, who are now more nobly or more usefully serving their country, either with the sword or with the plough? It was in consequence of experiments upon the nature of heat and pure physical investigations.

In every part of the world manufactures made from the mere clay and pebbles of your soil may be found; and to what is this owing? To chemical arts and experiments. You have excelled all other people in the

products of industry. But why? because you have assisted industry by science. Do not regard as indifferent what is your true and your greatest glory. Except in these respects, and in the light of a pure system of faith, in what are you superior to Athens or to Rome? Do you carry away from them the palm in literature and the fine arts? Do you not rather glory, and justly too, in being, in these respects, their imitators? Is it not demonstrated by the nature of your system of public education, and by your popular amusements? In what, then, are you their superiors? In every thing connected with physical science; with the experimental arts. These are your characteristics. Do not neglect them. You have a Newton, who is the glory, not only of your own country, but of the human race. You have a Bacon, whose precepts may still be attended to with advantage. Shall Englishmen slumber in that path which these great men have opened, and be overtaken by their neighbours? Say, rather, that all assistance shall be given to their efforts; that they shall be attended to, encouraged, and supported.

In congratulating you on the present era of philosophical discovery, and on the dawn of a new science now opening upon us, I cannot conclude without adverting to what, in these peculiar times, appears to me a deep and interesting truth.*

The scientific glory of a country may be considered, in some measure, as an indication of its innate strength.

* [This extract in praise of experimental philosophy, and in one of its noblest relations,—its influence on the spirit of the age, and its tendency to strengthen rational freedom, and preserve a people from a brutal or irrational despotism,—is from a lecture on electrical science, delivered in May 1808 or 1809, when the subjugation of Europe was threatened by the military power of France :—]

The exaltation of reason must necessarily be connected with the exaltation of the other noble faculties of the mind; and there is one spirit of enterprise, vigour, and conquest, in science, arts, and arms.

Science, for its progression, requires patronage; but it must be a patronage bestowed, a patronage received with dignity. It must be preserved independent. It can bear no fetters; not even fetters of gold; and, least of all, those fetters in which ignorance or selfishness may attempt to shackle it.

And there is no country which ought so much to glory in its progress, which is so much interested in its success, as this happy island. Science has been a prime cause of creating for us the inexhaustible wealth of manufactures; and it is by science that it must be preserved and extended. We are interested as a commercial people,—we are interested as a free people. The age of glory of a nation, is likewise the age of its security. The same dignified feeling, which urges men to endeavour to gain a dominion over nature, will preserve them from the humiliation of slavery. Natural, and moral, and religious knowledge, are of one family; and happy is that country, and great its strength, where they dwell together in union.

I have disclosed all that I know upon the matter [a chemical process, which the author believed might prove useful to the arts, and lucrative to any individual who might employ it;] and it will be a source of infinite satisfaction to me, if the publication of these statements should lead ingenious men into the path of inquiry. You, I trust, will do credit to my motives. I have no wish to conceal any thing which may be a source of

profit, even to others: for I hold *that science* in little estimation which is applied to selfish commercial speculation: the true object of discovery should be knowledge and intellectual power; and these cannot be purchased by thousands—and, in my humble estimation, are equivalent to millions.*

[The public institutions in the metropolis for the promotion of useful knowledge, are daily becoming of more importance and interest, in proportion as their influence is felt and appreciated. As a record of the author's sentiments on the state of the British Museum, and his views for its improvement, it may be right to insert here his remarks on the subject, written from his dictation, during his last illness at Rome. He had thought much respecting the British Museum, having been well acquainted with the establishment in the capacity of Trustee, as President of the Royal Society.

The subject is introduced incidentally, in noticing the collections of the objects of natural history in America, in connection with science in America, and her men of science, in digression from the character of the late Dr. Woodhouse, who brought him a letter of introduction, in 1804, from the venerable Priestley.]

I believe no country can be placed lower than our own, in respect to collections in ancient art, or modern science. A few liberal-minded patriotic men have done much by their private collections; and some particular institutions or colleges, by their private means, have afforded resources to scientific men; but our national establishment, the British Museum, is unworthy of a great people,—and is even inferior to many of those

* [From a lecture of 1810.]

belonging to second-rate states on the Continent; yet there have been considerable sums of money devoted to the objects of this collection, and it contains some choice marbles, and some interesting specimens in natural history; and far more might have been done with the sums voted for the purpose by Parliament, had they been judiciously applied.

When the British Museum was first established, in consequence of the bequest of Sir Hans Sloane, President of the Royal Society, of his splendid collections to the country, the trustees were either great officers of state, owing their situation to their office, or some persons of science, arts, and letters, associated with them elected by the principal trustees. At first, the principal trustees of the elected class, were either distinguished members of the Royal Society, or highly accomplished noblemen and gentlemen, possessed of refined knowledge in art, or profound knowledge in science. The last scientific trustee elected, was Mr. Henry Cavendish. Lately the elections have been almost entirely made from branches of the aristocracy, or gentlemen of some parliamentary influence. The Archbishop of Canterbury, the Lord Chancellor, and the Speaker of the House of Commons, are considered as the really active members of the trust; and overpowered as those great officers must be with the religious, legal, and legislative affairs of the country, it cannot be supposed that they can have much leisure or much opportunity to attend to the government or arrangement of the national collections.

All the officers of the Museum, who ought to be either efficient librarians, or curators of the house, used to be elected in turns, by the Archbishop of Canterbury and the Speaker of the House of Commons; for the late

Lord Chancellor Eldon, always refused to act as trustee, considering probably, with great propriety, that he had other duties, more essential to his office, to perform. It is not, therefore, to be wondered at, that amongst the curators, assistant librarians, and sub-librarians, there should be found many persons taken from the inferior departments of the church, and of the public offices; places abounding with respectable well-educated men, but not the natural seminaries of either naturalists, or of persons of profound and refined taste in antiquities, collections of the works of art, and monuments of the genius of the great people of antiquity.

If men of the highest distinction as to scientific character had always occupied the most exalted offices in the museum, either as curators of the collections, or as zoologists, ornithologists, entomologists, mineralogists, botanists, and superintendents of the ancient collections of sculpture and painting; and if the salaries of such officers had been made respectable, and their rank a gratifying or enviable one, there would have been always a sufficient number of aspirants after such situations, and we should not have required the assistance of foreigners in that establishment which ought to be the national school of our academies in science and art. But unfortunately, in England science is not the taste either of the court or of the government, and what might be the most magnificent collection of the beauties and wonders of nature and art, formed from every quarter of the globe, and containing the most splendid monuments of the glory of the most powerful of the ancient nations of the earth, does in fact represent little more than a series of quaint collections in vertu, where illustrations of the history of medals, and the most exquisite specimens of the bronzes of Magna Græcia

are found in the same room with the sledges and dresses of the Esquimaux, the canoes, arms and dresses of the people of Australasia, and the wildest ornaments invented either by the capricious or diseased fashions of folly in almost every climate and age. Even the first and most perfect part of the marbles brought from Athens to enrich the Hotel of Montague-house are out of place.

There must be a general system of change in everything belonging to this institution, before there can be any system of radical improvement. Each department must be preserved separate and distinct from the other. The sculpture must be judged by men who have shown their knowledge of taste with regard to this branch of the fine arts. The collection and arrangement of paintings must be trusted either to artists themselves or to refined judges of the art. The geologist should have his department entirely to himself, and the mineralogist would not find even the present treasures of the British Museum too extensive for much active labour, philosophical research, and even useful discovery in the variety of their arrangements and bearings; and a good geologist by connecting the history of the specimens of inorganic nature with those of living animals, might open to the world a number of curious and very extraordinary truths. Then the libraries should be kept perfectly distinct from the other parts of the museum; and there should be at least four enlightened and literary men of ability to take charge of these treasures now made so magnificent by the royal gift, and to lay them open to the public.

It appears to me that the present is the best moment for attempting a radical and fundamental change in everything belonging to this ancient, misapplied, and, I

may almost say, useless institution. In every part of the metropolis people are crying out for knowledge; they are searching for her even in corners and bye-ways, and such is their desire for her that they are disposed to seize her by illegitimate means if they cannot obtain her by fair and just ones. This then is the moment to give energy to their efforts, and for the legislature to sanction what reason has so long required.

The King's College is about to be formed, as a sort of counterpoise to the London University. Both must do good: and if the most useful part of the treasures of the British Museum, and of the Royal library could be transferred to Somerset House, and with the remains of the Royal Society, its books, its MSS., and its collections, form a Newtonian College, founded by his Majesty George IV., intended to perpetuate the memory and exalt the glory of the science which stands alone in the world, no higher boon could be given to posterity, for it is one in which not only Britain, but even Europe is interested.

END OF VOL. VIII.

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